# CALCULATION OF CONTAMINANT CONCENTRATIONS WHILE COATING THE INTERIOR OF A BULK STORAGE FUEL TANK

1990

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# CALCULATION OF CONTAMINANT CONCENTRATIONS WHILE COATING THE INTERIOR OF A BULK STORAGE FUEL TANK

A Study in

Mechanical Engineering

by

Gail Maureen Haberlin

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# NOMENCLATURE

English

a - constant, defined by mathematical expression
$AS_i$ - Surface Area of slice i
$C_{ave}$ - Average contaminant concentration to which a worker is exposed
$c_i$ - contaminant concentration in slice i
Em - Exposure Parameter
$f_{ij}$ - Percentage of air flow out of slice i and into slice j which is a scalar multiple of overall volumetric flow rate, Q (exchange factor)
ft - feet
g - grams
$g_s$ - evaporation rate during spraying
$g_d$ - evaporation rate during drying
h - time step
hr - hour
JP-5 - jet fuel used by the Navy
$k_i$ - percentage of total volume within a slice
Kad - Adsorption coefficient
kg - kilograms
m - meter
$m_A$, $m_B$, - mass of component A, mass of component B
mg - milligrams
$m_{voc}$ - mass of volatile hydrocarbons
MW - molecular weight
N - slice designation
Q - Volumetric Flow Rate
R - Remainder term in Taylor Series expansion
S - Source
Slice - Wedge-shaped piece of tank; area created by vertical cut through tank
t - time
V - Overall tank volume
$X_i$ - Percentage of outside air flowing into slice i
$Y_i$ - Percentage of air from slice i to the outside

$y_i$ - mass fraction of substance i

x, y, z - spatial coordinates

Greek

$\Sigma$ - summation

$\int$ - integral

Subscripts

$( )_A$ - of component A

$( )_B$ - of component B

$( )_d$ - quantity as it relates to drying

$( )_i$ - property in slice i, into slice i, out of slice i or of species i

$( )_{ij}$ - scalar value out of slice i and into slice j

$( )_{mix}$ - property of mixture

$( )_N$ - quantity as it relates to "Nth" slice

$( )_s$ - quantity as it relates to spraying

$( )_t$ - total quantity

$( )_{voc}$ - volatile hydrocarbon

$( )_{voc,t}$ - total volatile hydrocarbon

Superscripts

$( )'$ - first derivative

$( )^{(n)}$ - nth derivative

Abbreviations

ACGIH - American Conference of Governmental and Industrial Hygienists

ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers

CAS - Chemical Abstract Service
CFM - Cubic feet per minute
d( )/d( ) - total derivative
MSDS - Material Safety Data Sheets
NAVFAC - Naval Facilities Engineering Command
NFGS - Naval Facilities Engineering Command Guide Specification
OSHA - Occupational, Safety and Health Administration
PEL- Permissible Exposure Level
PPM - Parts per million
PTS - Petroleum Tank Services of Charlotte, North Carolina
SBM - Sequential Box Model
TDI - Toluene Diisocyanate
TLV - Threshold Limit Value

# CHAPTER 1

## INTRODUCTION

In the last decade we, as a society, have made great strides in the field of Occupational Safety and Health. The smarter we become about the hazards that surround us the more we need to learn. It is not enough to know that a substance provides a potential risk to an individual but we need to know what that risk is; specifically in a particular occupational activity, when does exposure to a chemical become hazardous and what are the effects of the exposure.

For many years engineers have been working on numerical solutions of the Navier-Stokes equations for 3-D turbulent flow in closed spaces [1]. In principle the problem is solved using finite difference methods coupled with a turbulence model. However, todays computers have difficulties in handling problems with complex boundary conditions. The reason for this is that data capacity is too small and the calculation time too long for many practical applications. Another problem is that turbulence models may not have the necessary accuracy for solving industrial ventilation problems.

As measurements are essential for performance assessment, models are essential for design. Many problems in industrial ventilation can be solved by using small scale physical flow models [2,3]. In other cases, even small scale models are regarded as too expensive. The development, application and validation of

mathematical models can provide designers, building operators, building occupants, and public officials the tools to relate the design of the physical system to maximum allowable concentrations, dose and anticipated human response. Both empirical and rational models are being developed for predicting the effectiveness of ventilation for acceptable indoor air quality.

Air quality may be defined as the characteristics of air that affect an individual's health and well-being in a salubrious way. More technically, air quality is a quantitative indicator of how well air satisfies three requirements for human occupancy: 1) thermal acceptability; 2) normal concentrations of respiratory gases (i.e., oxygen, nitrogen and carbon dioxide); and 3) suppression of other contaminants below levels that are deleterious to health or produce unpleasant odors [4]. It is the third indicator that is the focus of this paper.

In general, there are two methods used to design effective industrial ventilation systems: 1) prescriptive and 2) performance. Prescriptive methods to ventilate occupied spaces for acceptable air quality can be traced back to about 1600 A.D., when King Charles I declared that ceilings had to be at least 10 feet high and windows had to be higher than they were wide [4]. "Ventilation Rate Procedure" outlined in the ASHRAE Standard 62-1989 specifies the amount of outdoor air to be supplied to various occupied spaces [5]. Such prescriptive codes and standards provide design criteria which can be inspected and evaluated during design and construction, but they provide no assurances that occupant exposure will be acceptable. Prescriptive codes and standards are conventionally

established by consensus processes which are highly dependent upon historically accepted values and depend little upon scientific or mathematical techniques such as modeling . Conversely, performance standards are more frequently based on scientific and medical data than are prescriptive codes and standards and they can be enforced when the space is occupied, but they offer little guidance on how to design or construct systems that will provide the required control.

Whenever toxic or flammable vapor or gas is generated or contained within an enclosed space, a potential hazard exists. The philosophy behind any environmental sampling depends on the nature of the contaminant. In the case of a toxic substance, the individual is at risk and his exposure will determine his response [6]. Working in enclosed spaces requires many measures of contaminant control such as administrative controls, engineering controls and personal protective devices [7,8]. Administrative controls include but are certainly not limited to areas such as work practices, labeling and warning systems, educating personnel, waste disposal practices, environmental monitoring, assignment scheduling, medical surveillance, maintenance, sanitation, housekeeping and management. Engineering controls may be categorized by elimination methods, substitution, isolation, enclosure, process changes, product changes and industrial ventilation. Finally, personal protective devices vary from face masks to full helmet respirators with air provided through air lines to an outside source and include such personal gear as gloves, goggles, overalls, safety harnesses, hard hats and steel-toed boots. In all cases, engineers must be

able to predict or anticipate contaminant exposure and the associated health risk in order to effectively prescribe adequate methods of contaminant control.

Since the establishment of the Occupational Safety and Health Administration (OSHA) industrial hygienists have defined Permissible Exposure Levels (PEL) to concentrations of toxic substances. Similarly, the American Conference of Governmental and Industrial Hygienists (ACGIH) have defined Threshold Limit Values (TLV) to concentrations of toxic substances. Today, both the PEL's defined by OSHA and the TLV's defined by the ACGIH are used. Merely knowing the TLV of a substance is not enough, what is needed is a way to correlate the TLV's to an industrial process which generates the contaminant in question. Therefore, a means to forecast contaminants, generated by an industrial process or operation, to determine the potential health risk, caused by the process, must be developed.

The objectives of this study were to:

1) Devise an easy way to model a complex process in a confined space and to predict contaminant concentrations as functions of time and location, i.e., $c = c(x, y, z, t)$
2) Assess quantitatively the hazard caused by the industrial process
3) Recommend ways to reduce this hazard or exposure to acceptable limits.

The beauty of this study is in the simplicity and the applicability of the approach. The modeling process shown here may be used to determine exposure as a function of time and space in either enclosed spaces or in partial enclosures as the reader will see in the following chapters.

# CHAPTER 2

## PROBLEM DEFINITION

To demonstrate one method of evaluating the potential health risk associated with an industrial process, a study of U. S. Navy owned bulk fuel tanks which must be coated on the inside with a polyurethane coating system to extend their useful life was analyzed. Based on a "time value of money" or other economic analysis, it is less expensive to recoat an existing tank than it is to replace it. With economics in mind, the practice of coating tanks rather than replacing them will continue and only the nature of the toxic substances in the paint will change. To predict the concentrations as functions of time and location, $c = c(x, y, z, t)$, a technique called the "sequential box model" [9,10,11] was used to develop an analytical model and a fourth order Runge-Kutta subprogram was used to solve the set of linear, ordinary, simultaneous differential equations [12,13,14].

The particular case studied was the polyurethane coating of three U. S. Navy owned tanks at the Naval Air Station in Meridian, Mississippi. The document which described the process by which the contractor was to coat the tanks was the Department of the Navy, Naval Facilities Engineering Command Guide Specification 09872, October 1987 (NFGS-09872). A copy of the NFGS-09872 is provided in Appendix A. This performance specification not only provided information regarding the products to be used but also the execution

of the coating process and the safety and health measures which were to be employed. Information regarding actual contractor practices was provided by Petroleum Services, Incorporated of Charlotte, North Carolina. The paints used were manufactured by Rowe Paint Manufacturing Company of Jacksonville, Florida.

The tanks were made of steel and used to hold jet fuel (JP-5) used by the Navy [15]. Each tank had a capacity of approximately 1,110,000 gallons, was 77 feet in diameter and 32 feet tall. Each tank contained a "floating pan" which is an impermeable barrier that "floated" on the top surface of the fuel and rose and fell as fuel entered or left the tank. The purpose of the pan was to provide a vapor seal and to prevent the fuel from evaporating. The only entries into the tanks were a 20" manhole in the roof, a 20" manhole in the side of the tank, near the bottom, and a six-inch gauge hatch (providing access to valves and pressure gauges) in the roof. A sketch of a typical tank is shown in Figures 1 and 2 [16].

In order to analyze the air quality effectively and to determine the potential hazard of painting the tank, it was first necessary to determine the concentration of hydrocarbon vapor generated during painting in the tank. As stated before, this was done using a technique called the "sequential box model".

Prior to coating, the tank was emptied and cleaned. Details of this process were not considered in the model but could be included in future models if workers inside the tank used toxic materials. The method used to clean petroleum tanks is described in the Department of the Navy Guide Specification 13219, February 1988 (NFGS-13219). A copy of NFGS-13219 is provided in Appendix B. In

# TYPICAL TANK CONFIGURATION

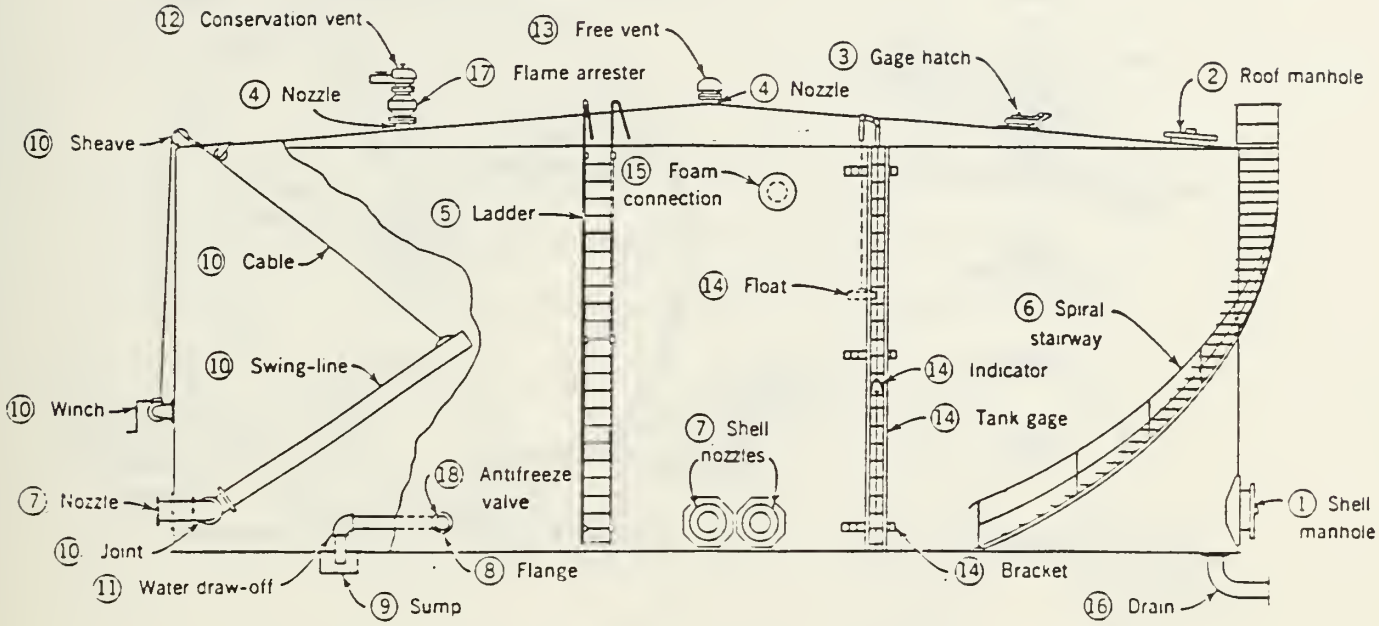



Fig. 3.13. Usual accessories and fittings on standard cone-roof tanks. (Courtesy of Hammond Iron Works.)

Included as standard

1. One 20" shell manhole
2. One 20" roof manhole
3. One 6" gauge hatch
4. Roof nozzle for vent (12 or 13)
5. Ladder (small tanks only)
6. Spiral stairway
7. Two shell nozzles
8. Flange for water draw-off

Included as extra

9. Sump
10. Swing line unit complete
11. Water draw-off
12. Conservation vent (volatile products)
13. Free vent (nonvolatile products)
14. (a) Target-type float gauge
14. (b) Ground-reading-type float gauge
15. Connection for foam chamber
16. Drain
17. Flame arrester
18. Antifreeze valve
1–8 Extra units
5. (a) Inside ladder

FIGURE 1

(Reproduced from Process Design Equipment, Ref. 17)

# TYPICAL TANK CONFIGURATION

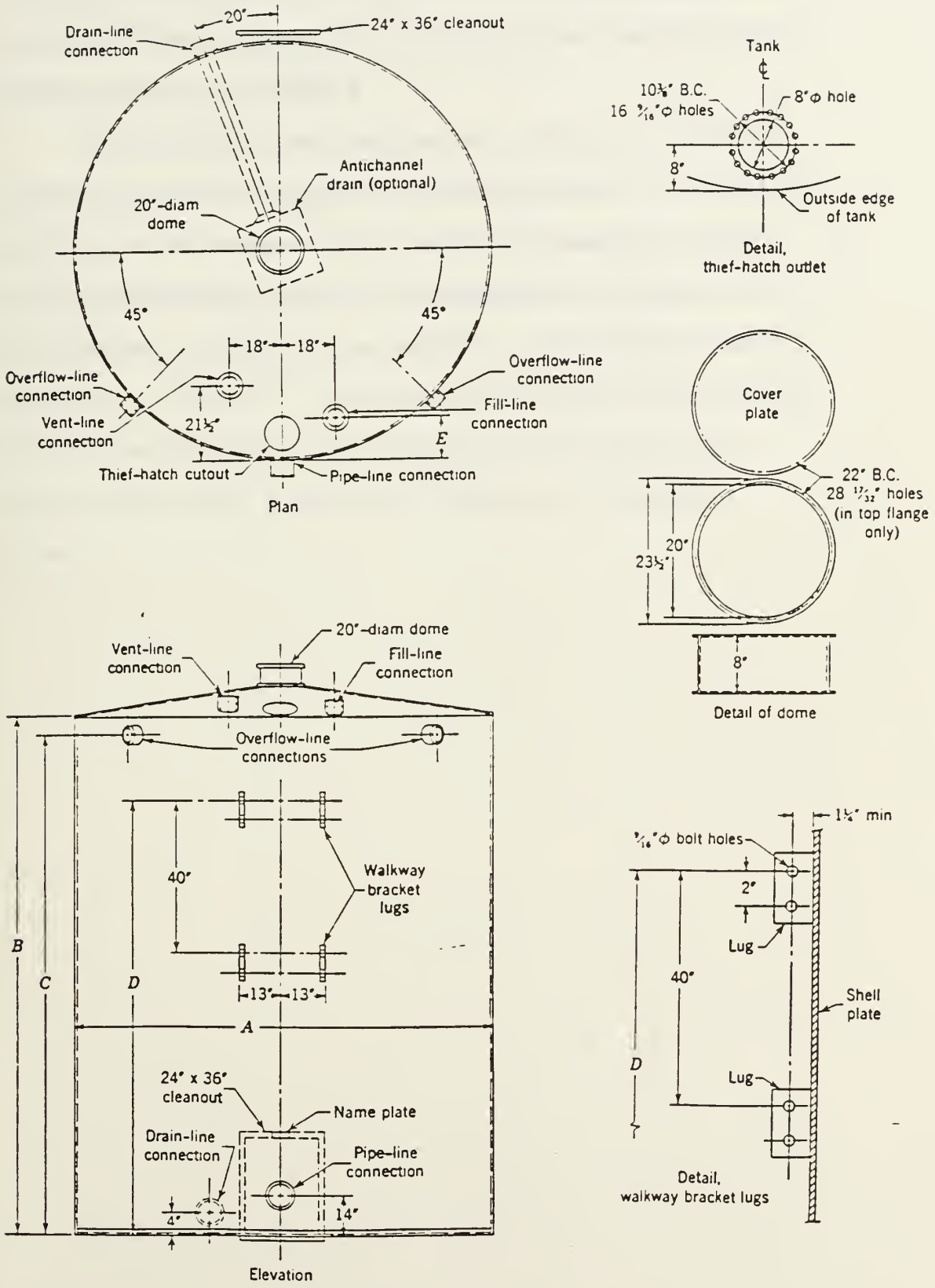



FIGURE 2

(Reproduced From Process Design Equipment, Ref. 17)

this case, it was assumed that the tank was cleaned, repaired and ready for the new coating system. For a complete description of the coating process see Chapter 4.

The two fundamental variables in this computer model were the source generation rate and the exchange factors. The exchange factors are scalar multiples of the overall volumetric flow rate and represent the amount of air which passes between two slices. A more detailed explanation of the selection of the exchange factors is provided in Chapter 5. Four cases were studied to determine the effects of varying the source generation rate and the exchange factors in this model. A summary of the cases is provided in Table 1.

# TABLE 1

## SUMMARY OF CASE STUDIES

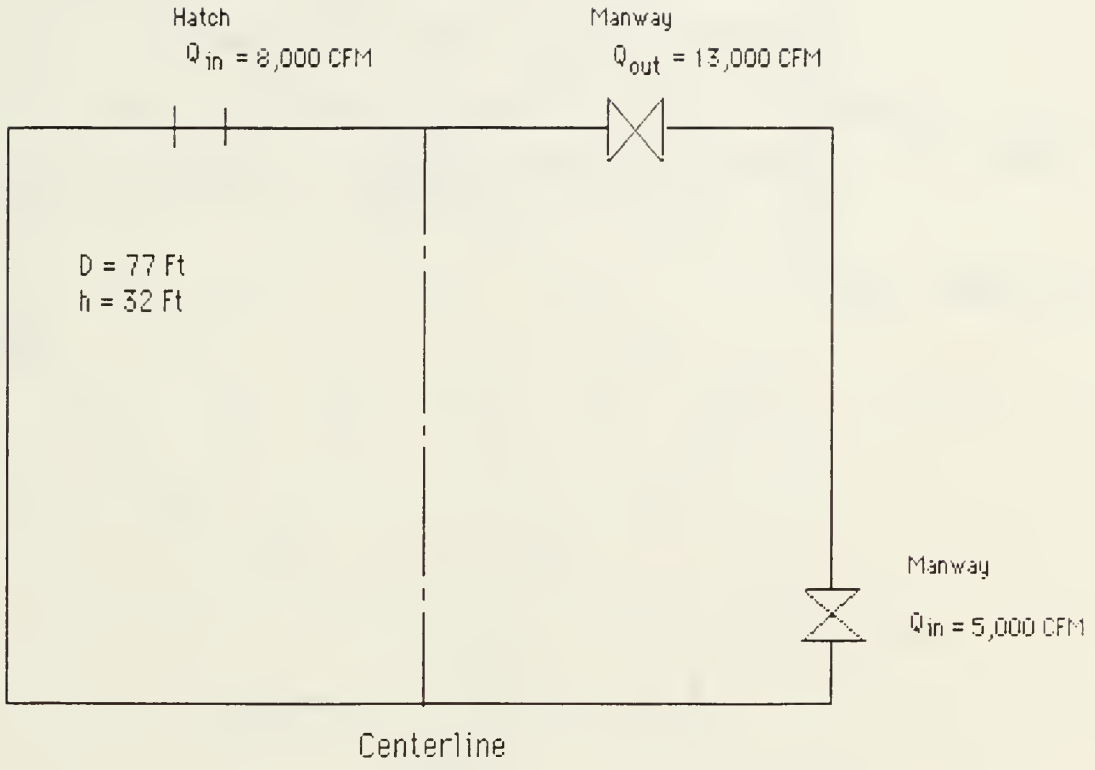
| Parameter | | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|---|
| SOURCE - walls/ceilings | | | | | |
| Wash Primer - | spray | 9139 5 | 9139 5 | 9139 5 | 10130 |
| | dry | 9083-18166 6 t | 9083-18166 6 t | 9083-18166 6 t | 2088-4176 t |
| Poly Primer - | spray | 4527 3 | 4527 3 | 4527 3 | 5030 2 |
| | dry | 4459 4-1783 8 t | 4459 4-1783 8 t | 4459 4-1783 8 t | 3891 9-1556 7 t |
| Intermediate - | spray | 2600 6 | 2600 6 | 2600 6 | 5197 9 |
| | dry | 2549 3-364 2 t | 2549 3-364 2 t | 2549 3-364 2 t | 1436 2-205 2 t |
| Top Coats - | spray | 2871 1 | 2871 1 | 2871 1 | 4621 7 |
| | dry | 2838 2-567 6 t | 2838 2-567 6 t | 2838 2-567 6 t | 1787 9-357 6 t |
| SOURCE - pan | | | | | |
| Wash Primer - | spray | 9282 1 | 9282 1 | 9282 1 | 9557 9 |
| | dry | 9220-18438 t | 9220-18438 t | 9220-18438 t | 5909 6-11819 2 |
| Poly Primer - | spray | 5489 9 | 5489 9 | 5489 9 | 6252 |
| | dry | 5486 8-2194 7 t | 5486 8-2194 7 t | 5486 8-2194 7 t | 3657 9-1463 1 t |
| Intermediate - | spray | 5140 3 | 5140 3 | 5140 3 | 6483 7 |
| | dry | 5012.9-716 1 t | 5012.9-716 1 t | 5012.9-716 1 t | 2709 6-387 1 t |
| Top Coats - | spray | 5062 3 | 5062 3 | 5062 3 | 5765 |
| | dry | 5059 5-1011 9 t | 5059 5-1011 9 t | 5059 5-1011 9 t | 3373 0-674 6 t |
| EXHANGE FACTORS | | | | | |
| fab | | 1 | 0 5 | 0 1 | 1 |
| fbd | | 0 5 | 0 25 | 0 1 | 0 5 |
| fde | | 0 | 0 | 0 1 | 0 |
| feh | | 0 | 0 | 0 05 | 0 |
| fhj | | 0 | 0 | 0 05 | 0 |
| fjk | | 0 5 | 0 5 | 0 25 | 0 5 |
| fkl | | 0 5 | 0 5 | 0 25 | 0 5 |
| flm | | 0 5 | 0 5 | 0 3 | 0 5 |
| fmp | | 0 5 | 0 5 | 0 5 | 0 5 |
| fpa | | 1 | 0 75 | 0 7 | 1 |
| fba | | 1 5 | 1 | 0 9 | 1 5 |
| fdb | | 0 62 | 0 37 | 0 52 | 0 62 |
| fed | | 0 12 | 0 12 | 0 52 | 0 12 |
| fhe | | 0 12 | 0 12 | 0 47 | 0 12 |
| fjh | | 0 12 | 0 12 | 0 47 | 0 12 |
| fkj | | 0 | 0 | 0 05 | 0 |
| flk | | 0 | 0 | 0 05 | 0 |
| fml | | 0 | 0 | 0 1 | 0 |
| fpm | | 0 | 0 | 0 3 | 0 |
| fap | | 0 5 | 0 25 | 0 5 | 0 5 |
| f12 | | 1 | 0 5 | 0 76 | 1 |
| f23 | | 0 38 | 0 38 | 0 38 | 0 38 |
| f34 | | 0 38 | 0 38 | 0 38 | 0 38 |
| f21 | | 0.62 | 0 12 | 0 38 | 0 62 |
| f32 | | 0 | 0 | 0 | 0 |
| f43 | | 0 | 0 | 0 | 0 |

# CHAPTER 3

## DETERMINATION OF SOURCE
## (RATE OF GENERATION OF HYDROCARBON VAPOR)

This chapter will address the rate at which hydrocarbon vapors were generated during the painting. Because the information was used to predict the contaminant concentration where individuals worked, it was important to estimate the source generation rate as a function of time and location within the tank for the actual work schedule. To do this both the NFGS-09872 and the work of Petroleum Tank Services (PTS) of Charlotte [17], North Carolina were consulted. Rowe Paint Manufacturing Company of Jacksonville, Florida [18] provided actual specifications and Material Safety Data Sheets (MSDS) for the coating system used by Petroleum Tank Services on tanks in Meridian, Mississippi. These data are provided in Appendix C.

The painting was performed in approximately ten (10) equal 24-foot sections (measured along the perimeter) each station taking approximately one and one half hours to complete. The tank was therefore divided into ten (10) wedge shaped sections, called "slices", and lettered a, b, d, e, h, j, k, l, m and p. Figures 3 and 4 depict the tank as described above. With an arc length of 24 feet and an height of 32 feet, the total surface area of each slice was 1233 $ft^2$, including the ceiling. The rate at which the slices were coated remained constant throughout the process at approximately

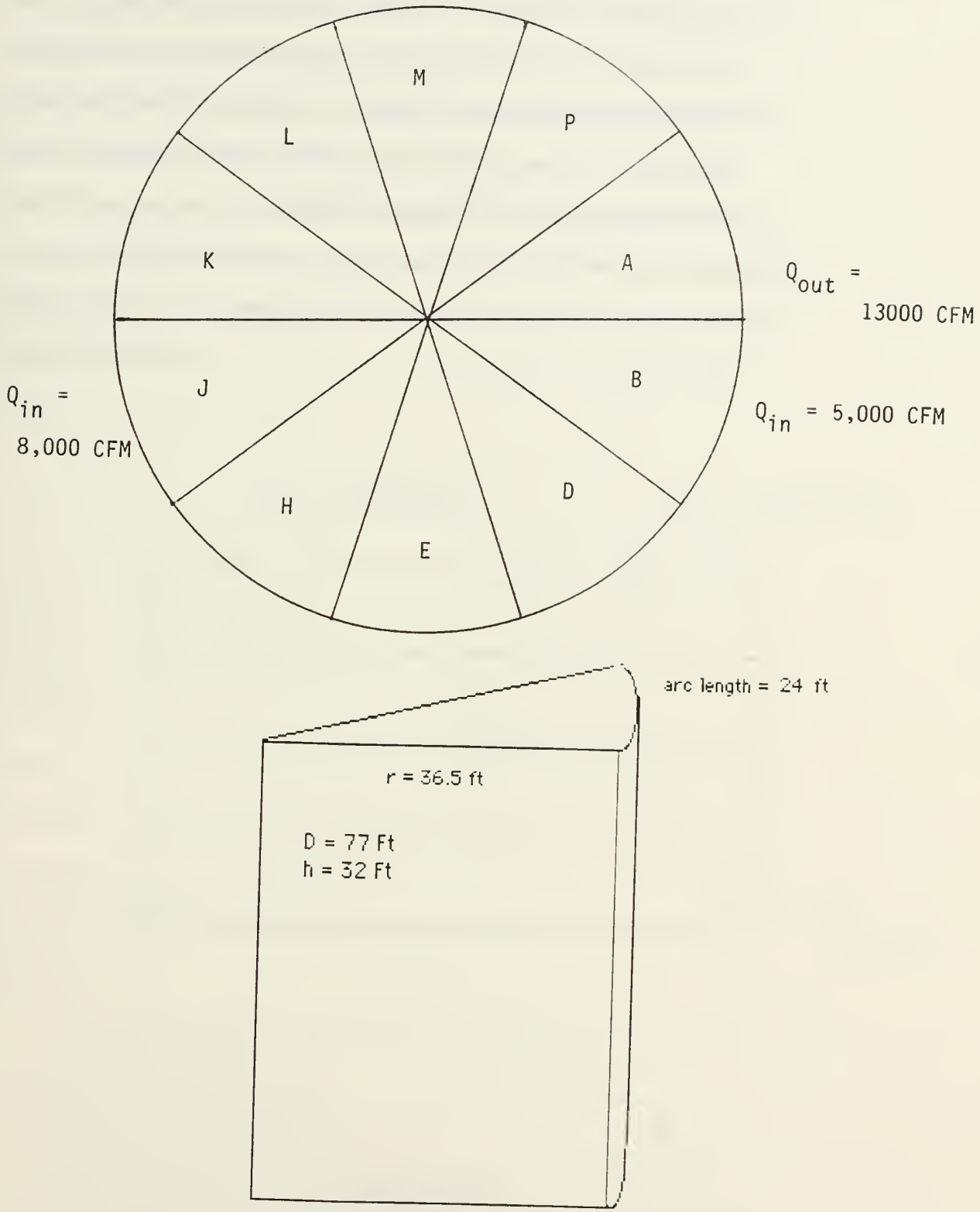



Tank Geometry

(not to scale)

Figure 3

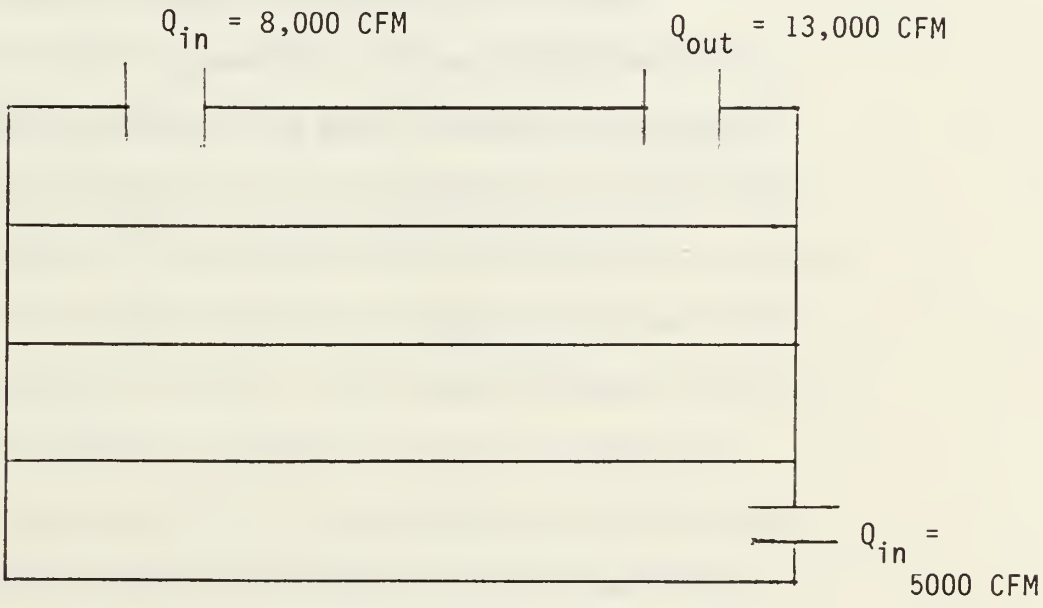
822 $ft^2$/hr. In the bottom of the tank there was a structure called the "floating pan" which rested on top of the fuel providing a vapor seal when the tank was filled with JP-5. When the tank was emptied, the "floating pan" rested approximately six inches off of the base of the tank. The "floating pan" was coated after all of the




DIVIDED TANK
10 WEDGED-SHAPED SECTIONS

FIGURE 4

interior walls and ceiling were coated. To model this stage in the process, the tank was divided into four horizontal "slices", each with a circular cross section. Figure 5 shows the reconfiguration of the tank "slices" prior to coating the "floating pan". The surface area of the pan was calculated as 4656 $ft^2$ and took approximately six hours to apply one coat. It was assumed that the rate of painting ($ft^2$/hr) to apply one coating to the pan was the same as in the tank slices (822 $ft^2$/hr).




Divided Tank
4-Cylindrical Sections

Figure 5

In general, hydrocarbon vapors were generated during spraying when then workers were in a slice "N" and for a short time afterward during drying when the workers were in the adjacent slice "N+1". After the coating had dried, the hydrocarbon generation (source) term was zero. Thus the model became N ordinary differential equations for $dc_N/dt$ for each of the "N" slices. In each equation, there was a source term that varied with real time. The solution consisted of solving the N simultaneous, linear, coupled ordinary differential equations.

Each coating provided a distinct source of volatile hydrocarbons for which a generation rate was established. In this study, a volatile, as defined by the paint manufacturing company's MSDS's, was any material with the normal boiling point below 425 degrees Fahrenheit. For the purpose of the model, all of the volatile hydrocarbons were lumped together as a single source and all men working in one area as "one man". This meant that each man in the slice would be subjected or exposed to the same contaminant concentration as the next man. For an analysis of a single contaminant, an individual hydrocarbon could be singled out as the sole source.

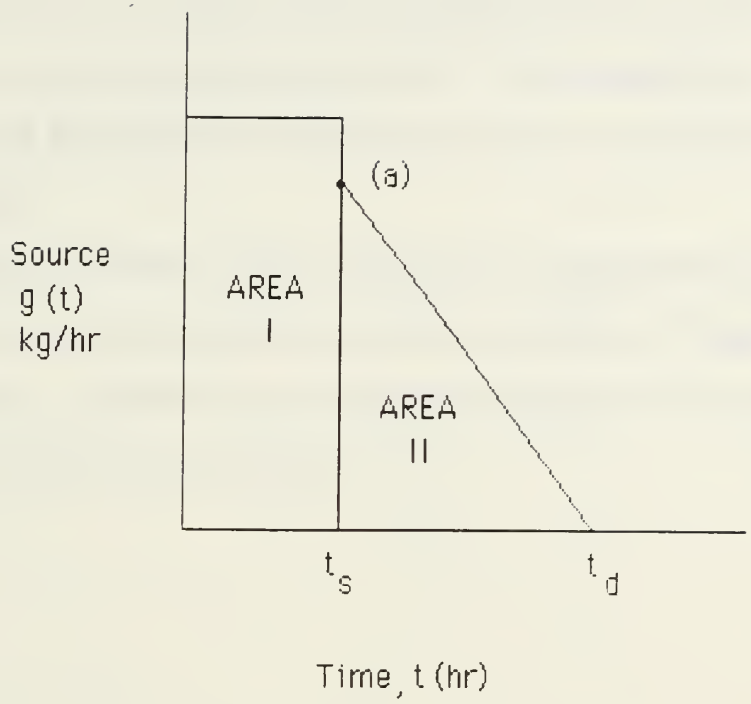
The coating system consisted of five stages:

(1) wash primer
(2) polyurethane primer
(3) polyurethane intermediate coat
(4) first polyurethane top coat
(5) second polyurethane top coat

In the remainder of the study, the terms, "wash prime", "prime", "intermediate" , "first top" and "second top" coats will be used. Once the total volatile content was identified, the amount released during spraying, including overspray, and the amount released during evaporation were estimated. The hydrocarbon emission rate was assumed to be constant during the spraying and a linearly decreasing function of time while the coating dried. The source generation rate was then defined for that coating as a function of time. In all cases, the total mass generated per coating was equal to the amount released during spraying plus the amount released during evaporation. In reference to Figure 6, Area I is the total amount of hydrocarbon vapor emitted during spraying and Area II is the total amount of hydrocarbon vapor emitted during drying. The total mass of hydrocarbon vapor can be determined by the following relationship:

$$\text{TOTAL SOURCE, } S = \int g(t)\, dt \qquad [1]$$

Point "a" represents the emission rate at the beginning of the drying period. Its value depends on a calculation. For the first set of calculations, point "a" was estimated to be approximately equal to the emission rate during the spraying operation. For the wash-primer which was 88 percent volatile, it was assumed that 85.5 percent of the hydrocarbons were emitted during the spraying operation and only 14.5 percent were emitted as a result of drying. In the case of the polyurethane primer, it was assumed that 54




Source Generation Curve
for Polyurethane Primer Coat

Figure 6

percent of the hydrocarbons were emitted during spraying and 46 percent during drying. For the intermediate coat, which had a much longer drying period, 29 percent was emitted during spraying and 71 percent during drying. Finally, in the case of the top coats, it was estimated that 36.5 percent was emitted during spraying while the remaining 63.5 percent was emitted during drying. These assump-

tions seemed to be reasonable in lieu of knowing the actual emission rates based on experimental measurements. The sequential box model could use any analytical or tabulated function for the solvent evaporation rate.

A sample calculation of the hydrocarbons emitted during the polyurethane primer coat using the information provided in Table 2 are shown below. Appendix D is a detailed breakdown of the calculations of the remaining source terms.

TABLE 2

Polyurethane Primer Data
(Rowe Paint Mfg. Co.)[18]

- Mixing Ratio: 4 parts A to 1 part B
- gallons per slice = 5

| COMPONENT A COMPOUNDS | % VOL | MW | TLV (PPM) | TLV ($g/m^3$) |
|---|---|---|---|---|
| (1) Zinc Chromate | 33.6 | 506.9 | 0.0024 | $5 \times 10^{-5}$ |
| (2) Glycol Ether EE | 7.7 | 132.07 * | 5 | 0.027 |
| (3) Ethyl Acetate | 7.7 | 88.11 | 400 | 1.40 |
| (4) n-Butyl Acetate | 7.7 | 116.16 | 150 | 0.710 |
| (5) Aromatic Hydrocarbon | 7.7 | 92 | 100 | 0.375 |
| (6) Other (unspecified additives) | 35.6 | | N/A | N/A |

- specific gravity = 1.47
- percent volatile by volume (%) = 48.7

* MW estimated from the chemical formula for ethylene glycol monoethyl ether acetate ($CH_3CH_2OCH_2CH_2OOCCH_3$)

| COMPONENT B COMPOUND | % VOL | MW | TLV (PPM) | TLV ($g/m^3$) |
|---|---|---|---|---|
| (1) Ethyl Acetate | 25 | 88.11 | 400 | 1.4 |
| (2) Aromatic Polyisocyanate | 75 | | Not Estab | --- |
| (3) Toluene Diisocyanate (TDI) (CAS# 26471-62-5) | * | 174 | 0.02 Ceiling (OSHA) | $1.4 \times 10^{-4}$ |

* TDI residual monomer content is less than 0.7% based on resin solids

- specific gravity = 1.19
- percent volatile by volume (%) = 34

CALCULATION:

Mass of component A used in each slice:

$$m_A = (4 \text{ gallons}) (1 \text{ m}^3/264.3 \text{ gallons}) (1470 \text{ kg/m}^3) \quad [2]$$

$$= 22.2472 \text{ kg}$$

Mass of volatile hydrocarbons in A in each slice:

$$m_{voc,A} = (0.487) (22.2474 \text{ kg}) = 10.8344 \text{ kg} \quad [3]$$

Mass of component B used in each slice:

$$m_B = (1 \text{ gallon}) (1 \text{ m}^3/264.3 \text{ gallon}) (1190 \text{ kg/m}^3)$$

$$= 4.5025 \text{ kg} \quad [4]$$

Mass of volatile hydrocarbons in B in each slice:

$$m_{voc,B} = (0.34) (4.5025 \text{ kg}) = 1.5308 \text{ kg} \quad [5]$$

The sum of equations [ 3 ] and [ 5 ] provides the total mass of volatile hydrocarbons in each slice:

$$m_{voc,t} = 10.8344 + 1.5308 = 12.3652 \text{ kg} \quad [6]$$

From literature regarding spray painting procedures, it was estimated that there was a 2 % overspray (0.2473 kg) during this operation and that the associated hydrocarbon vapors were emitted directly into the air.

As stated earlier, it was estimated that 54 % of the volatile hydrocarbons were emitted during spraying operations, while the remaining 46 % were emitted while drying. Additionally, it took approximately one and one half hours to coat a single slice. From this information, the total amount of volatile hydrocarbons emitted during spraying, or Area I of figure 6 was found from the following relationship:

$$g_S\,(1.5) = (0.54)\,(12.3652 - 0.2473) + 0.2473$$

$$= 6.7910 \qquad [7]$$

Where $g_S$ is the rate of generation of hydrocarbon vapor while spraying

$$g_S = 4.5273 \text{ kg/hr} \qquad [8]$$

Area II of figure 6, which represents the total amount of volatile hydrocarbons emitted while drying was found by:

$$[\,(a)\,(2.5)\,] / 2 = (0.46)\,(12.3652 - 0.2473) = 5.5742 \qquad [9]$$

$$a = 4.4594 \text{ kg/hr}$$

Since the source was assumed to decrease linearly with time, the rate of generation of hydrocarbon vapor emitted while drying, $g_d$, was found using Equation [ 10 ].

$$g_d = a - \{ a / (t_d - t_s) \} t \qquad [ 10 ]$$

or

$$g_d = 4.4594 - 1.7838\ t \qquad [ 11 ]$$

The summation of areas I and II represent the total hydrocarbon vapor that was in the air due to the application of the coating and became the basis of calculating the Threshold Limit Values (TLV) of the coating mixture and ultimately the exposure parameter.

## 3.1 DETERMINING THE THRESHOLD LIMIT VALUES

In order to evaluate the health effect caused by the exposure of the workers to the contaminants, a Threshold Limit Value was established for each coating. The TLV's identified on the Material Safety Data Sheets, a copy of which are provided in Appendix C, were used in calculating an overall TLV for each coating and an exposure parameter (Em) for each 40 hour work week in the entire process. The TLV of a liquid mixture was determined using the following relationship [19]:

$$(\text{TLV - mixture})\ (g/m^3) = [\ \Sigma\ (\ y / \text{TLV}\ )_i\ ]^{-1} \qquad [12\ ]$$

where $\Sigma$ denotes the summation over i compounds, $y_i$ denotes the

mass fraction of species i in the liquid phase and $TLV_i$ is the TLV of species i expressed in $g/m^3$. For a liquid mixture containing two components, as in the case of this study, the mass fraction of each species was determined as follows:

Component A: contained species $A_1$ through $A_i$

Component B: contained species $B_1$ and $B_j$

The mixing ratios $r_A$ and $r_B$ were:

$$r_A = m_A/m_t \quad [13]$$

$$r_B = m_B/m_t \quad [14]$$

The mass fractions for the species in components A and B were:

$$y_{A,i} = m_{A,i}/m_A \quad [15]$$

$$y_{B,j} = m_{B,j}/m_B \quad [16]$$

where

$$m_A = m_{A,1} + m_{A,2} + \ldots + m_{A,i} \quad [17]$$

and

$$m_B = m_{B,1} + m_{B,2} + \ldots + m_{B,j} \quad [18]$$

The total mass of the coating was:

$$m_t = m_A + m_B \quad [19]$$

$$m_t = m_{A,1} + m_{A,2} + \ldots + m_{A,i} + m_{B,1} + m_{B,2} + \ldots + m_{B,j} \quad [20]$$

$$= m_A (m_{A,1}/m_A + m_{A,2}/m_A + \ldots + m_{A,i}/m_A) + m_B (m_{B,1}/m_B + m_{B,2}/m_B + \ldots + m_{B,j}/m_B) \quad [21]$$

$$1 = (m_A/m_t)(y_{A,1} + y_{A,2} + \ldots + y_{A,i}) + (m_B/m_t)(y_{B,1} + y_{B,2} + \ldots + y_{B,j}) \quad [22]$$

$$1 = r_A \Sigma y_{A,i} + r_B \Sigma y_{B,j} \quad [23]$$

The final mass of the liquid mixture $m_t$ consisted of s species, where s was the number of distinct compounds ( note some compounds could appear in both components A and B). Therefore,

$$m_t = m_1 + m_2 + m_3 + \ldots + m_s \quad [24]$$

$$1 = m_1/m_t + m_2/m_t + m_3/m_t + \ldots + m_s/m_t \quad [25]$$

$$= y_1 + y_2 + y_3 + \ldots + y_s \quad [26]$$

where $y_s$ was the mass fraction of species s in the liquid mixture.

Below is a calculation of the TLV for the polyurethane primer coating described by the data provided in Table 2:

From equations [ 2 ] and [ 4 ] above:

$m_A = 22.2474$ kg

$m_B = 4.5025$ kg

therefore,

$m_t = m_A + m_B$

$m_t = 22.2474 + 4.5025 = 26.7499 \approx 26.75$ kg [ 27 ]

The mixing ratios and the mass fractions of the species in component A and B are indicated by the percentage of the species in each component identified in Table 2 are:

$r_A = 22.2474 / 26.75 = 0.8317 \approx 0.83$ [ 28 ]

$r_B = 4.5025 / 26.75 = 0.1683 \approx 0.17$ [ 29 ]

$y_{A,1} = 0.336$

$y_{A,2} = 0.077$

$y_{A,3} = 0.077$

$y_{A,4} = 0.077$

$y_{A,5} = 0.077$

$y_{A,6} = 0.356$

$y_{B,1} = 0.25$

$y_{B,2} = 0.75$

The mass fractions for the species in the overall liquid mixture were the same as those for the individual components except for ethyl acetate, which was represented by species A,3 and species B,1. Since ethyl acetate was used in both components, the mass fractions must be added together to determine the overall mass fraction. From equation [ 23 ]:

$$1 = r_A ( y_{A,1} + y_{A,2} + y_{A,3} + y_{A,4} + y_{A,5} + y_{A,6}) + r_B ( y_{B,1} + y_{B,2}) \quad [30]$$

$$1 = r_A y_{A,1} + r_A y_{A,2} + ( r_A y_{A,3} + r_B y_{B,1}) + r_A y_{A,4} + r_A y_{A,5} + r_A y_{A,6} + r_B y_{B,2} \quad [31]$$

$$1 = y_1 + y_2 + y_3 + y_4 + y_5 + y_6 + y_7 \quad [32]$$

Again, using the data provided in Table 2 and equations [ 31 ] and [ 32 ] the overall mass fractions for the polyurethane primer were calculated and are provided in Table 3.

TABLE 3

Mass Fractions for Compounds
in Polyurethane Primer

| MASS FRACTION | COMPOUND |
|---|---|
| $y_1 = (0.83)\ (0.336) = 0.2789$ | (Zinc Chromate) |
| $y_2 = (0.83)\ (0.077) = 0.0639$ | (Glycol Ether EE) |
| $y_3 = (0.83)\ (0.077) + (0.17)\ (0.25) = 0.1064$ | (Ethyl Acetate) |
| $y_4 = (0.83)\ (0.077) = 0.0639$ | (N-Butyl Acetate) |
| $y_5 = (0.83)\ (0.077) = 0.0639$ | (Hydrocarbons) |
| $y_6 = (0.83)\ (0.356) = 0.2955$ | (Other Additives)* |
| $y_7 = (0.17)\ (0.75) = 0.1275$ | (Polyisocyanates)** |

* Not hazardous, therefore was not included in the TLV calculation.

** TLV not established by OSHA or ACGIH, therefore was not included in the TLV calculation.

Finally, using equation [ 12 ], the TLV of the polyurethane primer coating mixture was found to be:

$$TLV_{mix} = [\ (0.2789 / 5 \times 10^{-5}\ ) + (0.0639 / 0.027\ ) + (0.1064 / 1.40\ ) + (0.0639 / 0.710\ ) + (0.0639 / 0.375\ )\ ]^{-1}$$

$$TLV_{mix} = [\ 5578 + 2.367 + 0.076 + 0.09 + 0.1704\ ]^{-1}$$

$$TLV_{mix} = 1.79 \times 10^{-4}\ g/m^3$$

Table 4 is a listing of the TLV's for the coatings used in the process.

TABLE 4

Threshold Limit Values

for Coatings

| Coating | TLV ($g/m^3$) |
|---|---|
| Wash Primer Coat | 4.700 |
| Polyurethane Primer Coat | $1.79 \times 10^{-4}$ |
| Intermediate Coat | 0.340 |
| 1st Top Coat | 0.411 |
| 2nd Top Coat | 0.411 |

# CHAPTER 4

## WORK SCHEDULE

It is only after understanding the work schedule that the reader can appreciate all of the elements that factor into determining whether the exposure was "safe". Because of time constraints set by the contract specifications, the contractor could only complete one tank at a time. Therefore a study of one tank was indicative of the results obtained in studying the other tanks. The complete tank coating process (for one tank) lasted approximately two weeks.

The contract required the removal of an existing epoxy coating and the installation of the polyurethane coating system. The first step in completing the contract was to drain the tank, clean the interior, patch any cracks, weld any holes, etc. In setting up the model it was assumed that the tank had already been cleaned and inspected. As mentioned previously there were different procedures and specifications under which tanks were cleaned. Although they were not included in this study, an analysis of the health effect of the cleaning process could also be conducted using the same techniques in this study. The time spent in preparing the tanks for coating was not included in the real-time model due to the fact that no contaminant was generated. However, for the reader's interest and understanding the tank preparation procedure will be described.

The work was to be performed from the top down and thus required the contractor to rig some sort of scaffolding or work platform inside the tank. In this case, "spider" scaffolding was rigged from the ceiling of the tank. The contractor drilled 1/2" holes around the ceiling and welded 3/4" couplers over the holes (couplers are devices used for locking together the components of a tubular metal scaffold [20]). Upon completion of the work inside the tank, steel plugs were placed in the holes which had been drilled. The scaffolding was hung inside the tank such that 24-foot boards could be used as platforms on which to work. Another type of scaffolding typically used is scaffolding is 15" across when folded, but unfolds to a section which is 5 feet by 7 feet [21]. Rigging the tank so that men could work safely and efficiently inside the tank was completed in approximately 3 days.

Three men worked on the 24-foot sections of platform moving around the tank interior (the circumference of the tank was approximately 242 feet). The sections overlapped six to twelve inches so that the coatings would overlap and no noticeable seams would occur where the coating would break down. The men used airless sprayers to apply the paint coatings. At the end of each hose was a 150 Watt lightbulb so that the men could see the surface that they were covering. The work progressed consecutively through the slices. In this way, there was never a time when there was work going on in more than one slice at a time. The "floating pan" which sat approximately 6 inches above the base was coated as one complete section after the tank walls and ceiling were completed.

The three men sandblasting in the tank wore protective clothing as required by OSHA, including throwaway 100% cotton overalls, leather gloves and full-helmet respirators with capes. Each man had a safety line which was hand-tended by a man on the roof of the tank. A13,000 CFM fan was installed in the 20-inch manhole on the roof of the tank to withdraw air from inside the tank. To add outside air to the tank, a 5000 CFM fan was installed in the manhole in the bottom of the tank. The only other ventilation from the exterior was from the open vents [22,23].

The first step in the process required sandblasting the inside surface of the tank "to white metal". At a rate of approximately 45 square feet per hour, sandblasting one slice took approximately 5.5 hours. Since the men blew the sand and debris to the bottom as they worked, the clean-up process after this phase lasted approximately one hour. The tank was then coated with five layers of material as discussed on page 16. The first coat was called a wash primer and was applied as soon after but no later than 8 hours after sandblasting and within 8 hours of mixing the solution. The painting process lasted 1.5 hours after which 0.5 hours was spent cleaning up and preparing for the second coat called the polyurethane primer. The polyurethane primer had to be applied no earlier than 0.5 hours and no later than 8 hours after the wash primer. In addition, this coat had to be applied within 3 hours after mixing the ingredients. The painting process again lasted 1.5 hours with 0.5 hours at the end for clean-up and preparation for the next segment of work. The polyurethane intermediate and top coats were applied succes-

sively allowing a drying time of no less than eight hours nor greater than 48 hours between each coat. The contract called for a second top coat to be applied if the total dry film thickness was less than 6 mils (152 microns). In this model, a second top coat was applied to each slice, but only one top coat was used for the "floating pan". This was based on the work actually performed by PTS [21,22,24].

Because there were several hours between the application of the polyurethane primer and intermediate coats, work began on a new slice. The second slice was prepared on the same schedule as the first slice, i.e., sandblast, wash primer and polyurethane primer coats, lasting a total of approximately 10 hours including clean up. The work on the tank was performed in two shifts of 10-13 hours each over the first few days. As the time between coats began driving the schedule, shifts of 8-10 hours per day were worked.

The following outline of the first few days of the schedule will demonstrate the interrelationship between the work in each slice and will therefore help to clarify the contaminant generation rate discussed in Chapter 3. The first day the first two slices were sandblasted, and the wash primer and polyurethane primer coats were applied in two separate 10 hour segments. On the second day, the same schedule was followed on the third and fourth slices. Following this, the intermediate coats were applied to the first and second slices. On the third day the fifth slice was sandblasted and the wash primer and polyurethane primer coats were applied after which the first top coat was applied to the

first and second slices and the intermediate coat was applied to the third and fourth slices successively. The fourth day called for sandblasting, wash priming and polyurethane priming the sixth slice, applying the second top coat on the first and second slices, the first top coat on the third and fourth slices and the intermediate coat on the fifth slice. At this point work was completed in the first two slices. Figure 7 provides a chart of the work progression through the first two slices. The total time to complete the work in the ten slices was ten days.

Once the work on the tank ceiling and sides was completed, work began on the "floating pan". Applying coatings to the "floating pan" followed the same sequence of coats and the same rates as in each slice but on a slightly different schedule. Sandblasting the "floating pan" lasted approximately 20 hours, while painting each of the various coats lasted six hours. Because of the long time required to coat such a large area, the sandblasting and priming of the "floating pan" was split into two halves and took two days. Therefore, on the eleventh day, one half of the pan was sandblasted and the wash primer and polyurethane primer coats were applied. On the twelfth day, the second half was sandblasted and the wash primer and polyurethane primer coats were applied. The thirteenth day was devoted to applying the intermediate coat on the whole pan. On the fourteenth day the top coat was applied and work was completed in the tank. A chart showing the complete "real-time" schedule is provided in Appendix E.

# WORK SCHEDULE THROUGH FIRST TWO "SLICES"

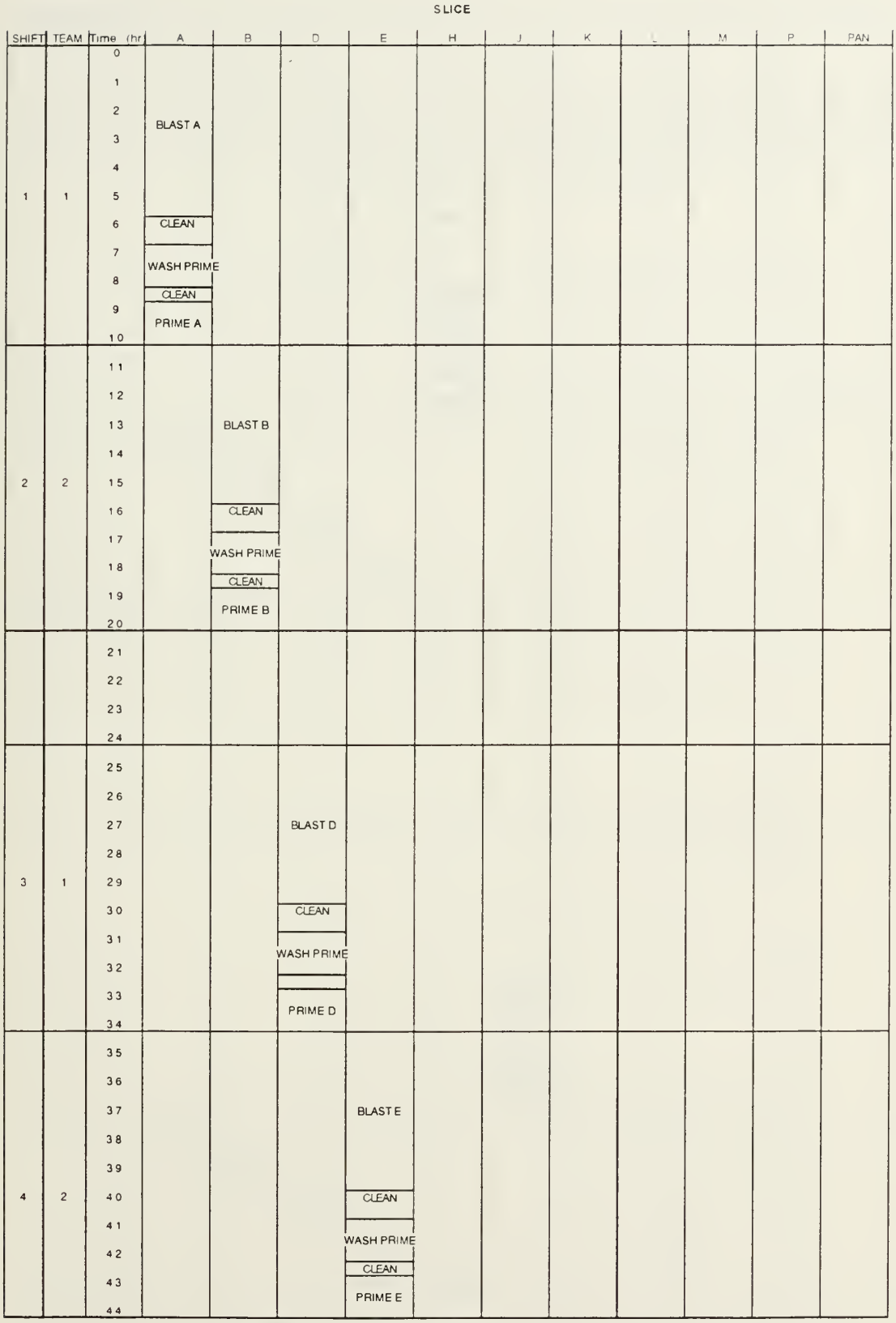



FIGURE 7

## WORK SCHEDULE THROUGH FIRST TWO "SLICES" (CONTINUED)

| SHIFT | TEAM | Time (hr) | A | B | D | E | H | J | K | L | M | P | PAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 45 | INT A | | | | | | | | | | |
| | | 46 | | INT B | | | | | | | | | |
| | | 47 | | | | | | | | | | | |
| | | 48 | | | | | | | | | | | |
| | | 49 | | | | | | | | | | | |
| | | 50 | | | | | | | | | | | |
| | | 51 | | | | | BLAST H | | | | | | |
| | | 52 | | | | | | | | | | | |
| 5 | 1 | 53 | | | | | | | | | | | |
| | | 54 | | | | | CLEAN | | | | | | |
| | | 55 | | | | | | | | | | | |
| | | 56 | | | | | WASH PRIME | | | | | | |
| | | 57 | | | | | CLEAN | | | | | | |
| | | 58 | | | | | PRIME H | | | | | | |
| | | 59 | 1ST TOP A | | | | | | | | | | |
| | | 60 | | 1ST TOP B | | | | | | | | | |
| 6 | 2 | 61 | | | | | | | | | | | |
| | | 62 | | | INT D | | | | | | | | |
| | | 63 | | | | INT E | | | | | | | |
| | | 64 | | | | | | | | | | | |
| | | 65 | | | | | | | | | | | |
| | | 66 | | | | | | | | | | | |
| | | 67 | | | | | | | | | | | |
| | | 68 | | | | | | | | | | | |
| | | 69 | | | | | | | | | | | |
| | | 70 | | | | | | | | | | | |
| | | 71 | | | | | | | | | | | |
| | | 72 | | | | | | | | | | | |
| | | 73 | | | | | | | | | | | |
| | | 74 | | | | | | | | | | | |
| | | 75 | | | | | | BLAST J | | | | | |
| | | 76 | | | | | | | | | | | |
| 7 | 1 | 77 | | | | | | | | | | | |
| | | 78 | | | | | | CLEAN | | | | | |
| | | 79 | | | | | | | | | | | |
| | | 80 | | | | | | WASH PRIME | | | | | |
| | | 81 | | | | | | CLEAN | | | | | |
| | | 82 | | | | | | PRIME J | | | | | |
| | | 83 | 2ND TOP A | | | | | | | | | | |
| | | 84 | | 2ND TOP B | | | | | | | | | |
| | | 85 | | | | | | | | | | | |
| 8 | 2 | 86 | | | 1ST TOP D | | | | | | | | |
| | | 87 | | | | 1ST TOP E | | | | | | | |
| | | 88 | | | | | | | | | | | |
| | | 89 | | | | | INT H | | | | | | |

FIGURE 7

# CHAPTER 5

## THE SEQUENTIAL BOX MODEL

The method used to predict the exposure of the workers to the contaminants generated in the tank as a function of time and space was called the Sequential Box Model (SBM) [7,8,9]. The SBM technique calculated the instantaneous as well as steady-state concentrations at various locations within the tank including the region where workers were spraying. Although more complicated numerical techniques could have been used to analyze this situation [14], the SBM was less costly and less time consuming than the numerical methods to solve the complete Navier-Stokes equations.

The first step in setting up the model was to divide the tank into a finite number of adjacent volumes called "sequential boxes". As described before, the tank was divided into 10 wedge-shaped slices to model the process while coating the sides and ceiling; and four cylindrical slices while coating the "floating pan". It was assumed that the concentration within each box was "well- mixed" and that by considering the concentrations in the individual boxes, a spatial estimation of the overall concentration with respect to time could be determined. In each case, the slices were chosen to represent the volumes in which men work. The following quantities were known based upon the given problem conditions:

a) Overall Volume ($m^3$)

b) Volume of each slice ($m^3$ chosen by author)

c) Mass flow rate of air into and out of the tank (since the density was constant throughout volume, the volumetric flow rate was used)

d) Location of inflow and outflow of air crossing the boundaries of the control volume

e) Instantaneous generation rate of the contaminant within each slice

The transport of air between adjacent slices was represented as a scalar multiple of the overall volumetric flow rate. These scalar multiples were called "exchange factors" ($f_{ij}$) and were chosen by the author. By convention, the first subscript, "i", in the exchange factor "$f_{ij}$" denoted the slice out of which air flowed and the second subscript, "j", indicated the slice into which air flowed. In each slice, the conservation of mass for air was satisfied, thus creating a set of equations which were solved simultaneously producing a set of exchange factors related to the exchange factors in the adjacent slices.

Validation of the selection of exchange factors could only be made by experimental means; however, one could select a range of values believed to be indicative of the actual flow conditions. For example, to account for the flow of air out of slice A, the exchange factors $f_{ab}$ and $f_{ap}$ apply. A further discussion of the initial selection and subsequent selections of exchange factors

will be made during the description of the SBM technique, in the following section, 5.1.

## 5.1 DESCRIPTION OF SBM

The overall tank volume was divided into 10 slices, each representing the region where the men worked during a particular shift and applied one layer of surface coating. Figures 3 and 4 show the tank configuration and the definition of slices. The slices were lettered A, B, D, E, H, J, K, L, M and P sequentially (the letters C, f and g were reserved for the concentration, the exchange factors and the source, respectively)

Once the slices were chosen a mass balance equation for the contaminant was written for each slice. For example the equation for Slice "A" was as follows:

$$k_a V [ dc_a/dt ] = S_a + f_{pa} Q c_p + f_{ba} Q c_b - [ f_{ap} Q + f_{ab} Q + X_a Q + Kad AS_a] c_a \quad [33]$$

which was rearranged as follows:

$$[ dc_a/dt ] = \{ ( f_{ap} Q + f_{ab} Q + X_a Q + Kad AS_a ) c_a \} / (k_a V) + ( S_a + f_{pa} Q c_p + f_{ba} Q c_b ) / ( k_a V ) \quad [34]$$

where:

Q = volumetric flow rate ($m^3$/min)

$V$ = overall volume of the tank ($m^3$)

$k_a$ = fraction of total volume represented by slice "A"

$c_a$ = contaminant mass concentration in slice "A" as a function of time ($g/m^3$)

$c_b$ = contaminant mass concentration in slice "B" as a function of time ($g/m^3$)

$c_p$ = contaminant mass concentration in slice "P" as a function of time ($g/m^3$)

$f_{ap}$ = fraction of total volumetric flow rate going from slice "A" into slice "P"

$f_{ab}$ = fraction of total volumetric flow rate going from slice "A" into slice "B"

$f_{pa}$ = fraction of total volumetric flow rate going from slice "P" into slice "A"

$f_{ba}$ = fraction of total volumetric flow rate going from slice "B" into slice "A"

$X_a$ = fraction of air coming into slice "A" from outside of the tank

$AS_a$ = surface area of Slice "A" ($m^2$)

Kad = adsorption factor (m/hr)

$S_a$ = Source generated in slice "A" as a function of time (g/hr)

$Y_a$ = fraction of air leaving slice "A" to the air outside of the tank

Performing a mass balance for air for slice "A" yields

$$0 = f_{ba} Q + f_{pa} Q - f_{ap} Q - f_{ab} Q - Y_a Q \quad [35]$$

Simplifying Equation [ 35 ] resulted in:

$$f_{ba} + f_{pa} - f_{ap} - f_{ab} - 1 = 0 \quad [36]$$

A similar analysis for each of the remaining slices yielded the following relationship for the exchange coefficients:

"B": $f_{ab} - f_{ba} - f_{bd} + f_{db} + 0.38 = 0$ [37]

"D": $f_{bd} - f_{db} - f_{de} + f_{ed} = 0$ [38]

"E": $f_{de} - f_{ed} - f_{eh} + f_{he} = 0$ [39]

"H": $f_{eh} - f_{he} - f_{hj} + f_{jh} = 0$ [40]

"J": $f_{hj} - f_{jh} - f_{jk} + f_{kj} + 0.62 = 0$ [41]

"K": $f_{jk} - f_{kj} - f_{kl} + f_{lk} = 0$ [42]

"L": $f_{kl} - f_{lk} - f_{lm} + f_{ml} = 0$ [43]

"M": $f_{lm} - f_{ml} - f_{mp} + f_{pm} = 0$ [44]

"P": $f_{mp} - f_{pm} - f_{pa} + f_{ap} = 0$ [45]

The mass balance equations while coating the "floating pan" were as follows:

"1": f21 - f12 + 0.38 = 0 [46]

"2": f12 - f21 - f23 + f32 = 0 [47]

"3": f23 - f32 - f34 + f43 = 0 [48]

"4": f34 - f43 - 0.38 = 0 [49]

As defined earlier in this chapter, the exchange factors are scalar multiples of the overall volumetric flow rate and represent the transport of air from one slice into another. Since validation of actual values for the exchange factors can only be made by experimental means, the author had to select a range of values believed to be indicative of the actual flow patterns within the tank. It was assumed that the air flow out of the tank through slice "A" dominated the flow within the tank. This was based on the fact that the air flow out of the tank through slice "A" was more than two times the amount into the tank through the adjacent slice "B", refer to Figure 4 on page 14. The air flow into the slice through tank "J" was assumed to "push" the air toward slice "A" which in turn was "pulling" the air.

The initial selection of the exchange factors was made based on the assumption that mass flow across the boundaries between adjacent slices was constant (except in those cases where outside air was introduced). For example, the flow across the boundary between slices "B" and "D" was equal to the flow across the boundary between slices "D" and "E" which was also equal to the flow across the boundary between slices "E" and "H". These assumptions resulted in the following sets of simultaneous

equations; for the slice walls and ceilings and for the pan, respectively:

"A": $f_{ab} - f_{ba} = 1 - f_{ap} + f_{pa}$ [50]

"B": $f_{ab} - f_{ba} = f_{bd} - f_{db} - 0.38$ [51]

"D": $f_{bd} - f_{db} = f_{de} - f_{ed}$ [52]

"E": $f_{de} - f_{ed} = f_{eh} - f_{he}$ [53]

"H": $f_{eh} - f_{he} = f_{hj} - f_{jh}$ [54]

"J": $f_{hj} - f_{jh} = f_{jk} - f_{kj} - 0.62$ [55]

"K": $f_{jk} - f_{kj} = f_{kl} - f_{lk}$ [56]

"L": $f_{kl} - f_{lk} = f_{lm} - f_{ml}$ [57]

"M": $f_{lm} - f_{ml} = f_{mp} - f_{pm}$ [58]

"P": $f_{mp} - f_{pm} = f_{pa} - f_{ap}$ [59]

"1": $f12 - f21 = 0.38$ [60]

"2": $f12 - f21 = f23 - f32$ [61]

"3": $f23 - f32 = f34 - f43$ [62]

"4": $f34 - f43 = 0.38$ [63]

Three different Case studies were made to determine the importance of the selection of exchange factors on the results of the model. In Case 1, it was assumed that the men stirred the air as they moved from slice to slice. In this way, the exchange

factors into and out of each slice changed as the men moved about. Throughout Case 1, it was assumed that the exchange factor out of the slice where the men worked was unity. The f's out of the adjacent slices was one half of the value and the remaining f's out of the slices was zero. It must be remembered however, that in all cases, the sets of equations [50] through [59] and [60] through [63] had to be satisfied simultaneously. Case 2 used f values 1/2 of the original f values out of the tank slices and maintained the assumption that the men stirred the air while they were spraying, requiring the f values to change as the men moved from slice to slice. Values of f less than unity indicated that there was very little movement of air between two slices. The "new" f values used in Case 3 were selected based on an intuitive estimation of how air would flow around the tank assuming the men did not stir the air while they painted. Again, the sets of equations [50] through [59] and [60] through [63] were satisfied. Table 5 is the selection of exchange factors used for Case 1, Case 2 and Case 3 (original f's, 1/2 times f and new f's) while painting in slice "A".

In using the SBM technique the only unknown was the contaminant concentration as a function of time. The location of the workers and the source generated as a function of time and space were defined earlier in chapter 3. A fourth order Runge-Kutta technique was used to solve the differential equations [12,13,14]. The Runge-Kutta method is a way to solving a problem of successive differentiation by transforming the ordinary differential equation to a series of algebraic expressions. Given a Taylor's Series expansion of the form:

TABLE 5

Selection of Exchange Factors
While Painting in Slice "A"
(extracted from Table 1)

| f | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| fab | 1.0 | 0.5 | 0.1 |
| fbd | 0.5 | 0.25 | 0.1 |
| fde | 0.0 | 0.0 | 0.1 |
| feh | 0.0 | 0.0 | 0.05 |
| fhj | 0.0 | 0.0 | 0.05 |
| fjk | 0.5 | 0.5 | 0.25 |
| fkl | 0.5 | 0.5 | 0.25 |
| flm | 0.5 | 0.5 | 0.3 |
| fmp | 0.5 | 0.5 | 0.5 |
| fpa | 1.0 | 0.75 | 0.7 |
| fba | 1.5 | 1.00 | 0.90 |
| fdb | 0.62 | 0.37 | 0.52 |
| fed | 0.12 | 0.12 | 0.52 |
| fhe | 0.12 | 0.12 | 0.47 |
| fjh | 0.12 | 0.12 | 0.47 |
| fkj | 0.0 | 0.0 | 0.05 |
| flk | 0.0 | 0.0 | 0.05 |
| fml | 0.0 | 0.0 | 0.1 |
| fpm | 0.0 | 0.0 | 0.3 |
| fap | 0.5 | 0.25 | 0.5 |
| | | | |
| f12 | 1.0 | 0.5 | 0.76 |
| f23 | 0.38 | 0.38 | 0.38 |
| f34 | 0.38 | 0.38 | 0.38 |
| f21 | 0.62 | 0.12 | 0.38 |
| f32 | 0.0 | 0.0 | 0.0 |
| f43 | 0.0 | 0.0 | 0.0 |

$$x(t + h) = x(t) + h\,x'(t) + (h^2/2!)\,x''(t) + (h^3/3!)\,x'''(t) + (h^4/4!)\,x^{(4)}(t) + R \qquad [64]$$

where h is the time step and R is a remainder term which can be neglected for very small values of h. If x'(t) is a function of t and x(t), the resultant solution would require complicated successive differentiation and an enormous amount of time. The Fourth Order Runge-Kutta technique, as used in this study transforms the above equation into the following:

$$x(t + h) = x(t) + (h/6)\,(m1 + m2 + m3 + m4) \qquad [65]$$

where: $m1 = h\,f(t, x)$

$m2 = h\,f(t + h/2, x + m1/2)$

$m3 = h\,f(t + h/2, x + m2/2)$

$m4 = h\,f(t + h, x + m3)$

This method of solution is ideal for practical applications as in this study because it is time-marching and is easily programmed on a computer. The fact that it is explicit could cause some stability problems which would be the result of taking a step size which is too large. Therefore, computations over a range of step sizes must be taken to ensure stability. In this study, Equation [34] and the subsequent equations governing the rate of contaminant concentration were rewritten in the form:

$$dc_i/dt = Ac_i + Bc_{i+1} + Dc_{i-1} + E \qquad [66]$$

where A, B, D, and E were coefficients which were constant over a time step h. This resulted in a coupled set of ordinary differential equations. The solution to Equation [66] was obtained by computing the concentration at the end of each time step for each slice. The concentration in each slice at the end of a time step became the initial value for the calculation at the next time step. The contaminant concentration in each slice was updated at every time step providing the most current estimate of the contaminant concentration in adjacent slices for the model. By summing these concentrations using the "actual" work schedule, the workers' exposure to the contaminants was determined.

# CHAPTER 6

## RESULTS

Using the procedures outlined in the previous chapters the contaminant concentration in each slice, as a function of time, were obtained and plotted in figures 8, 9 and 10. By tracing the worker's movement through the tank, the author was able to determine the worker's exposure as a function of time. This can be seen in Figure 11. The entire process was repeated for Cases 2 and 3. The concentrations were computed but are not shown. The results are interpreted in Chapter 8.

CASE 1

Concentration vs. Time
in Slices "a" through "h"

Q = 13,000 CFM

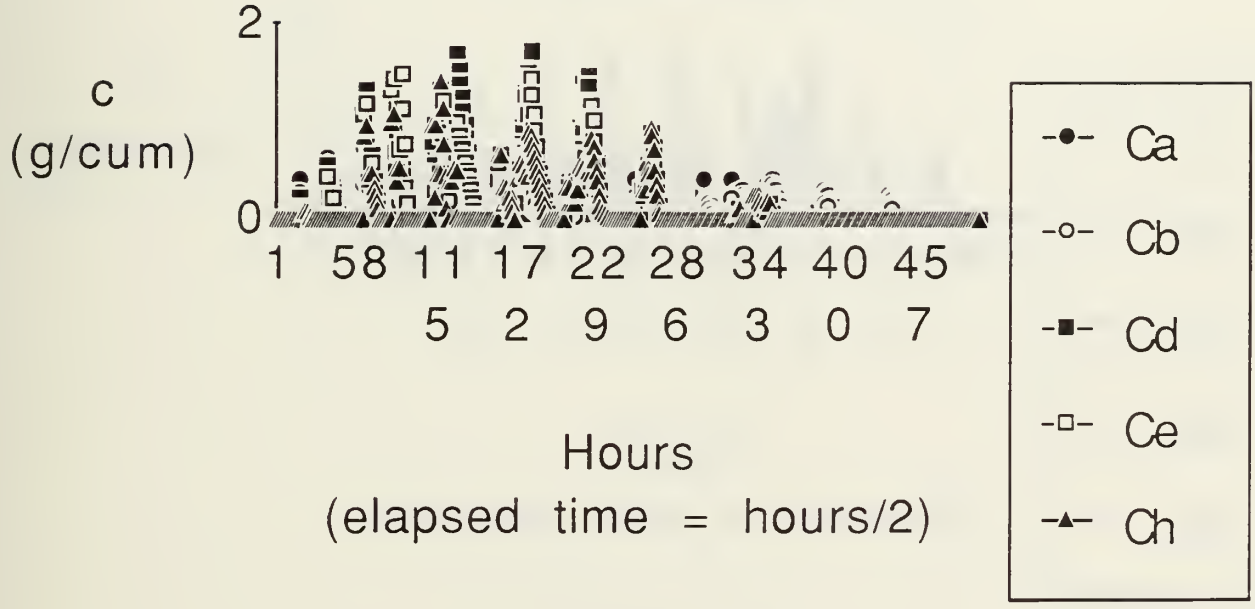



Figure 8

CASE 1

Concentration vs. Time
in Slices "j" through "p"

Q = 13,000 CFM

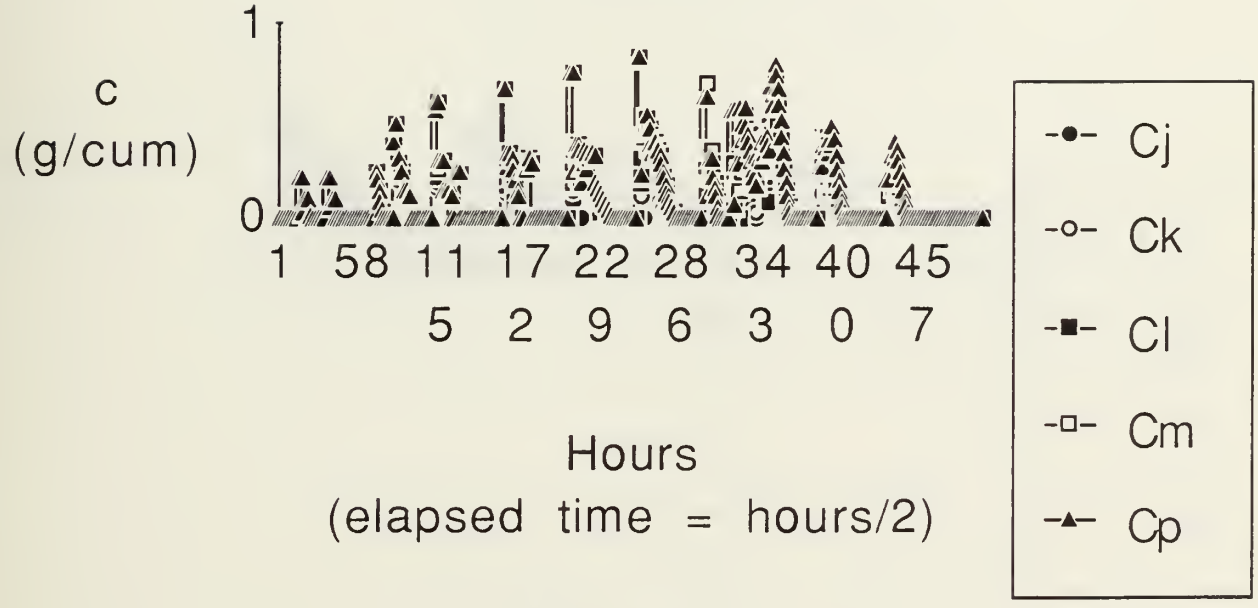



Figure 9

CASE 1

Concentration vs. Time
in Floating Pan

Q = 13,000 CFM

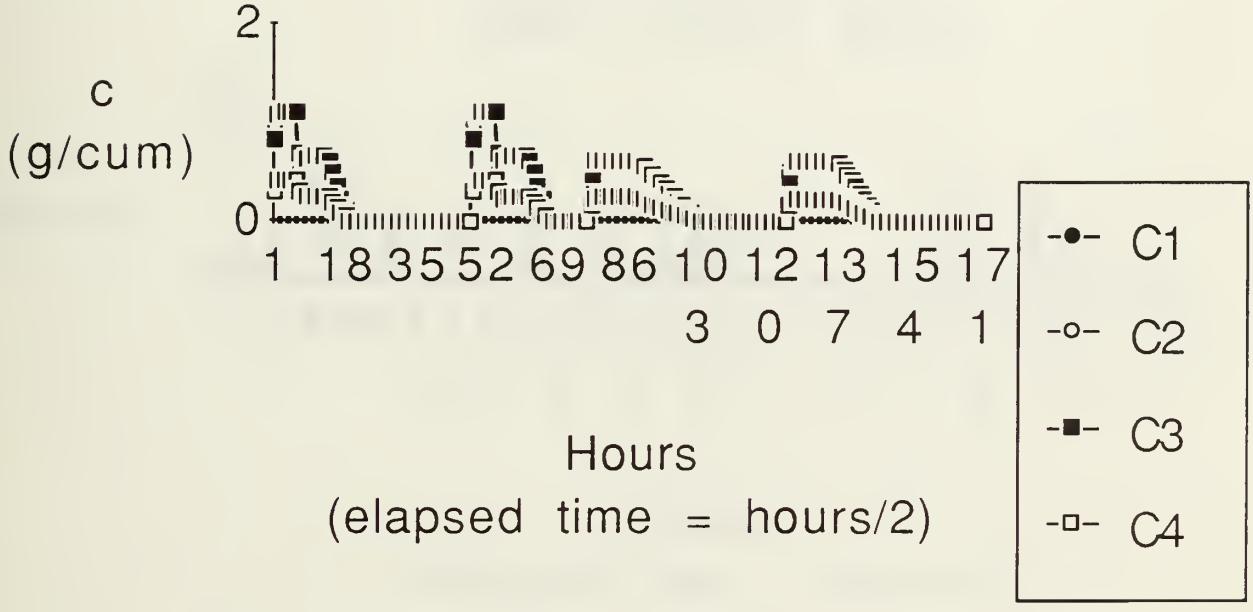
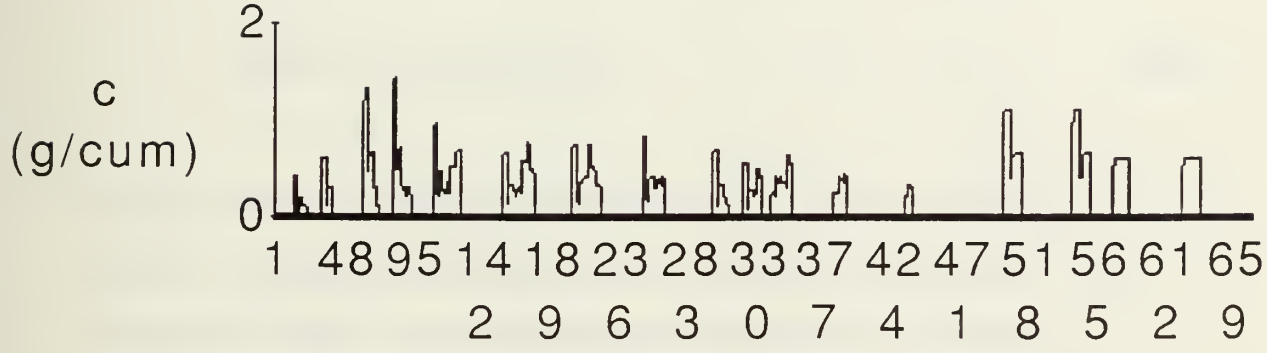



Figure 10

CASE 1

Contaminant Concentration
of Worker vs. Time

Q = 13,000 CFM
Cave = 0.1671 g/cum




Hours
(elapsed time = hours/2)

FIGURE 11

# CHAPTER 7

## INTERPRETATIONS

The first observation that can be made is that the concentration never reaches a steady-state condition. The large spikes in Figure 11, indicate that the worker concentration could be as much as three times the average concentration over the process defined by Eqn [67].

$$Cave = ( 1/ T) \sum ( c_i )( \partial t ) \qquad [67]$$

Table 6 shows the average concentration per shift (as indicated in Figure 7 on pages 29 and 30) per coat throughout the process. The hydrocarbon vapor is only generated while the men are working, therefore concentrations of hydrocarbon vapor were greatest where the men worked. As discussed in Chapter 4, the work schedule allowed for work to begin in a second slice while the paint dried in the first. As work progressed into the third and fourth slices, the accumulation of hydrocarbon vapor which had evaporated and that which was being emitted during spray painting a new slice became significant. This effect can be seen by the fact that the contaminant concentrations were greatest in slices D and E.

The next largest exposure was found while coating the "floating pan". This was due mainly to the size of the pan and the amount of hydrocarbon vapors emitted during the coating process.

TABLE 6

Average Concentration Worker is
Exposed to per Shift
($g/m^3$)

| Shift | Wash Primer | Primer | Int | 1st Top | 2nd Top |
|---|---|---|---|---|---|
| 1 | 0.12918 | 0.06146 | 0 | 0 | 0 |
| 2 | 0.22634 | 0.09202 | 0 | 0 | 0 |
| 3 | 0.43346 | 0.19683 | 0 | 0 | 0 |
| 4 | 0.44137 | 0.16397 | 0.12122 | 0 | 0 |
| 5 | 0.31002 | 0.14293 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0.46119 | 0.21187 | 0 |
| 7 | 0.21240 | 0.09898 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0.17805 | 0.49707 | 0.20269 |
| 9 | 0.23763 | 0.11090 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0.12282 | 0.18869 | 0.43387 |
| 11 | 0.26469 | 0.12266 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0.14353 | 0.13430 | 0.11301 |
| 13 | 0.21762 | 0.10242 | 0 | 0 | 0 |
| 14 | 0.17396 | 0.06306 | 0.10632 | 0.05406 | 0 |
| 15 | 0 | 0 | 0.28926 | 0.22222 | 0.21147 |
| 16 | 0 | 0 | 0 | 0.29790 | 0.09703 |
| 17 | 0 | 0 | 0 | 0 | 0.19854 |
| 18 | 0 | 0 | 0 | 0 | 0 |
| 19 | 0.86508 | 0.48739 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0.86508 | 0.48739 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0.90989 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0.89608 | 0 |

Recall, that the model was reconfigured as four cylindrically shaped slices, eight feet in height, while the "floating pan" was being coated.

To determine the hazard created by the chemicals released in the gas phase, an exposure parameter (Em) had to be calculated for each coating. The Em is defined by OSHA, based on a 40-hour week as [6] :

$$Em = \sum \{ ( y / TLV )_i \} \qquad [68]$$

where y is the mass fraction of the contaminant and $TLV_i$ is its threshold limit value expressed in $g/m^3$. If Em is less than one, the exposure can be considered safe. Conversely, if Em is greater than one, the exposure is unsafe and some measure of control must be implemented. Since the workers all wore full-helmet respirators it was expected that the exposure parameters would be greater than one. Therefore a comparison of four different cases was made. Case 1 provided the baseline by which the other three cases were compared. Cases 2 and 3 as indicated in Table 5 were used to determine the influence of the exchange factor on the exposure parameter. Case 4, which will be discussed in Chapter 8, compared the effect of the source generation rate on the exposure parameter.

For this study, an exposure parameter was determined for every four shifts which approximately represented a 40-hour work week. Using the data provided in Table 6, the exposure parameter per shift for Case 1 was determined and is provided in Table 7. As

expected, the results shown in Table 7 indicate that the process studied was extremely hazardous and this is why the workers wear protective clothing and auxiliary air supply. After a closer look at the factors that went into the calculation of the exposure parameter, the author contends that this is not entirely the case.

As the reader may recall, the calculation of the TLV in Equation [12] required taking the reciprocal of the summation of the mass fraction of species y, divided by its TLV. Therefore the dominant factor in the TLV calculation becomes the species with the lowest TLV. In this case, the zinc chromate, in the polyurethane primer, (with a TLV of $5 \times 10^{-5}$ $g/m^3$) affected the composite TLV most strongly. If the polyurethane primer did not contain zinc chromate but contained an alternate substance which was less toxic, its TLV would have been 0.369 $g/m^3$ which is of the same order of the intermediate and top coats.

To gain more insight into the potential health effect of the coating process, a calculation of the exposure parameter without the polyurethane primer coat was made and is shown in the third column of Table 7. Disregarding the polyurethane primer in its entirety still yielded Em's greater than one causing one to conclude that a potentially hazardous situation does exist. As a comparison to the exposure parameters calculated with and without the polyurethane primer, the adjusted Em is a calculation of the exposure parameter using a TLV of 0.369 $g/m^3$ for the polyurethane primer coating.

At this point the author took a more critical look at the assumptions made in the beginning of the modeling process. The

first assumption was that all of the workers would be treated as one, each receiving the same "dose" or exposure to the volatile hydrocarbons. In addition, the model calculated the contaminant concentration assuming that one worker performed all of the work. In reality, the work was performed by two alternating teams of three people each. With this in mind the concentration to which each worker was exposed, was greatly reduced. Table 8 provides the exposure parameters per team of worker, based on the schedule each team worked.

The data provided in Table 8 in conjunction with the work schedule provided in Appendix E (a partial work schedule is provided in Figure 7 on pages 31 and 32) indicates that the most hazardous situations occurred when multiple coatings were applied within the same shift and while the "floating pan" was being coated. Team 1 was responsible for the odd numbered shifts through shift #15 in Figure 7 and was responsible for all of the succeeding shifts (16 through 23). Team 2 was responsible for the even numbered shifts through shift #14 in Figure 7. From the pattern established by the work schedule, the reader can see that Team 1 was responsible for blast cleaning, applying the wash primer and polyurethane primer coats to a slice at the beginning of each shift. Team 2 followed with blast cleaning and applying the wash primer and polyurethane primer coats to an adjacent slice. As time passed and only one slice was blasted clean and the first two coats were applied, Team 2 became responsible for applying the subsequent coats to anywhere from two to five previously prepared slices (those which had been blasted clean and to which the wash primer and polyurethane

TABLE 7

Case 1
Exposure Parameter per Week

| Week | Em | Em Without Primer | Em (TLV=0.369)* |
|---|---|---|---|
| 1 | 718.436177 | 0.15457899 | 0.50301369 |
| 2 | 338.916729 | 1.05234402 | 1.2162403 |
| 3 | 326.958247 | 0.75168324 | 0.90992436 |
| 4 | 231.958502 | 0.84861811 | 0.96072832 |
| 5 | 680.876281 | 0.16678335 | 0.49699202 |
| 6 | 681.773807 | 1.06430979 | 1.39451846 |

* Calculation of Em based on a TLV for the polyurethane primer coating equal to 0.369 g/$m^3$

Table 8

Case 1
Exposure Parameter per Team

| | Week | Em | Em Without Primer | Em (TLV=0.369)* |
|---|---|---|---|---|
| Team 1 | 1 | 698.6729 | 0.057716 | 0.396610 |
| | 2 | 469.7655 | 0.514791 | 0.742422 |
| | 3 | 681.1165 | 0.407013 | 0.737221 |
| | 4 | 681.9696 | 1.260111 | 1.590319 |
| Team 2 | | | | |
| | 1 | 358.6800 | 1.149207 | 1.322644 |
| | 2 | 88.91104 | 0.845281 | 0.888001 |

* Calculation of Em based on a TLV for the polyurethane primer coating equal to 0.369 g/$m^3$

primer coats had been applied) within a shift. It is the addition of the contaminant concentration as the worker progressed through the slices that causes the exposure parameter to be so high. As in the first analysis, the time during which the "floating pan" was being coated was also potentially hazardous. This was due to the amount of material applied and the corresponding hydrocarbon vapor generated.

As mentioned earlier, the zinc chromate was the dominant factor in the magnitude of the exposure parameters established by this study. Years of studying the effects of zinc chromate on industrial workers [25,26,27] have indicated that exposure can result in such effects as perforated nasal septa, nosebleeds, perforated ear drums, kidney damage, erosion and discoloration of the teeth, dermatitis and asthmatic bronchitis [28]. Furthermore, the relative risk of dying from respiratory cancer among chromate workers is over 20 times the rate for the control population [29]. Although the ACGIH has set the TLV of zinc chromate at a level to prevent irritation of the nasal passages, the important point to make here, is the necessity of the workers and management to take wearing coveralls and other protective clothing seriously rather than being casual about it.

# CHAPTER 8

## EFFECTS OF VARYING PARAMETERS ON EXPOSURE PARAMETER

As discussed in Chapter 5, the selection of the exchange factor is of paramount importance to the validity and conclusiveness of this study. Table 5 on page 45 provided the exchange factors in slice "A" for Cases 1, 2 and 3 (reference values, 1/2 reference values, new values - assuming workers do not stir air as they progress through the tank). Tables 9, 10, 11 and 12 are the results of Cases 2 and 3.

### TABLE 9

Case 2
Exposure Parameter per Week

| Week | Em | Em Without Primer | Em (TLV=0.369)* |
|---|---|---|---|
| 1 | 880.9471 | 0.170132 | 0.597392 |
| 2 | 388.8188 | 1.202341 | 1.390372 |
| 3 | 332.9929 | 0.841692 | 1.002817 |
| 4 | 257.3541 | 0.876258 | 1.000674 |
| 5 | 676.8406 | 0.180526 | 0.508770 |
| 6 | 677.9257 | 1.265650 | 1.593894 |

* Calculation of Em based on a TLV for the polyurethane primer coating equal to 0.369 $g/m^3$

TABLE 10

Case 2
Exposure Parameter per Team

| | Week | Em | Em Without Primer | Em (TLV=0.369)* |
|---|---|---|---|---|
| Team 1 | 1 | 819.4745 | 0.067385 | 0.464875 |
| | 2 | 490.0652 | 0.521086 | 0.758561 |
| | 3 | 682.6871 | 0.441267 | 0.772221 |
| | 4 | 683.5115 | 1.265650 | 1.596603 |
| Team 2 | | | | |
| | 1 | 450.2914 | 1.305088 | 1.522889 |
| | 2 | 100.0211 | 0.936107 | 0.984173 |

* Calculation of Em based on a TLV for the polyurethane primer coating equal to 0.369 g/$m^3$

TABLE 11

Case 3
Exposure Parameter per Week

| Week | Em | Em Without Primer | Em (TLV=0.369)* |
|---|---|---|---|
| 1 | 530.2327 | 0.116822 | 0.373978 |
| 2 | 336.1656 | 0.637494 | 0.800257 |
| 3 | 733.8868 | 0.657175 | 1.012861 |
| 4 | 422.3359 | 1.483316 | 1.687470 |
| 5 | 681.3723 | 0.257068 | 0.587474 |
| 6 | 682.3771 | 1.261836 | 1.592241 |

* Calculation of Em based on a TLV for the polyurethane primer coating equal to 0.369 g/$m^3$

TABLE 12

Case 3
Exposure Parameter per Team

| | Week | Em | Em Without Primer | Em (TLV=0.369)* |
|---|---|---|---|---|
| Team 1 | 1 | 606.6997 | 0.048341 | 0.342624 |
| | 2 | 1013.877 | 0.841365 | 1.332783 |
| | 3 | 681.8227 | 0.707499 | 1.037905 |
| | 4 | 682.3771 | 1.261836 | 1.592241 |
| Team 2 | | | | |
| | 1 | 259.6985 | 0.705975 | 0.831611 |
| | 2 | 141.8949 | 0.848695 | 0.917116 |

* Calculation of Em based on a TLV for the polyurethane primer coating equal to 0.369 $g/m^3$

Of the various parameters which could be varied in SBM, the study has focused mainly on the exchange factors. One other area of concern is the actual make-up of the individual coatings and their TLV's. To get a better understanding of the effect of the source generation rate on the exposure parameter, Case 4 was developed. In this case, the same exchange coefficients were used as in Case 1, but the source generation rate was varied. To change to generation rate, the percentage of volatile hydrocarbons emitted during the spraying and drying operations was varied from Case 1. Table 13 provides a comparison of the percent hydrocarbon emitted in Cases 1 and 4. Tables 14 and 15 are the results of the data obtained by changing the source generation rate.

TABLE 13

Percentage of Volatile Hydrocarbons
Emitted for Case 1 and Case 4

| Coating | Operation | Case 1 | | Case 4 | |
|---|---|---|---|---|---|
| | | Walls | Pan | Walls | Pan |
| Wash Primer | Spraying | 85.5 | 92.2 | 95 | 95 |
| | Drying | 14.5 | 7.8 | 5 | 5 |
| Polyurethane | Spraying | 54 | 70 | 60 | 80 |
| Primer | Drying | 46 | 30 | 40 | 20 |
| Intermediate | Spraying | 29 | 63 | 60 | 80 |
| Coat | Drying | 71 | 37 | 40 | 20 |
| 1st & 2nd | Spraying | 36.5 | 70 | 60 | 80 |
| Top Coats | Drying | 63.5 | 30 | 40 | 20 |

TABLE 14

Case 4
Exposure Parameter per Week

| Week | Em | Em Without Primer | Em (TLV=0.369)* |
|---|---|---|---|
| 1 | 790.3611 | 0.199221 | 0.582524 |
| 2 | 376.0613 | 1.425033 | 1.606767 |
| 3 | 363.0202 | 1.011693 | 1.187301 |
| 4 | 253.0618 | 1.060717 | 1.182961 |
| 5 | 772.0625 | 0.209799 | 0.584221 |
| 6 | 773.3639 | 1.511219 | 1.885640 |

TABLE 15

Case 4
Exposure Parameter per Team

| | Week | Em | Em Without Primer | Em (TLV=0.369)* |
|---|---|---|---|---|
| Team 1 | 1 | 770.8892 | 0.060602 | 0.434527 |
| | 2 | 521.5319 | 0.625643 | 0.878331 |
| | 3 | 772.3588 | 0.506155 | 0.880576 |
| | 4 | 773.3639 | 1.511219 | 1.885641 |
| Team 2 | | | | |
| | 1 | 395.5332 | 1.563652 | 1.754764 |
| | 2 | 98.99355 | 1.150412 | 1.197875 |

* Calculation of Em based on a TLV for the polyurethane primer coating equal to 0.369 $g/m^3$

A comparison of the exposure parameter using a TLV equal to 0.369 $g/m^3$ for the polyurethane primer in each of the four cases yields the following results:

TABLE 16

Comparison of Exposure Parameters
in Cases 1, 2, 3 and 4
(based on a per team evaluation)

| | Week | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|---|
| Team 1 | 1 | 0.396610 | 0.464875 | 0.342624 | 0.434527 |
| | 2 | 0.742422 | 0.758561 | 1.332783 | 0.878331 |
| | 3 | 0.737221 | 0.772221 | 1.037905 | 0.880576 |
| | 4 | 1.590319 | 1.596604 | 1.592241 | 1.885641 |
| Team 2 | 1 | 1.322644 | 1.522889 | 0.831611 | 1.754764 |
| | 2 | 0.888001 | 0.984173 | 0.917116 | 1.197875 |

A comparison of the first two cases in which the exchange factor was halved (f values in Case 2 were 1/2 f values in Case 1), the exposure parameter for a given time period increased. When the exchange factors did not vary as the men moved from slice to slice, as in Case 3, the exposure parameter varied from less than one percent to a value which was greater than 75 percent of the values used in Case 1. This disparity in values indicates the importance of

knowing the actual air flow within the tank. A comparison of Case 1 and Case 4, in which the source generation rate was varied indicated that in those cases where it was assumed that the mass of hydrocarbon vapor emitted during spraying in Case 4 was greater than that of the reference case, Case 1, the exposure parameter increased. Conversely, in those cases where the mass of hydrocarbon vapor emitted during spraying in Case 4 was less than that of Case 1, the exposure parameter decreased. This is the expected result, yet again, stresses the importance of knowing more information about the painting compounds and their evaporation rates.

# CHAPTER 9

# CONCLUSION

The purpose of this study was threefold: 1) to devise and easy way to model a complex process in an enclosed space, 2) to anticipate and rate potential hazards and 3) to recommend ways to reduce the hazard. The first five chapters of this study were dedicated to the first objective and much time was spent explaining how the given process, or any process, could be modeled using the sequential box model technique. The major limitation to the method was in the uncertainty of the numerical value of the exchange coefficients. Without some means of measuring the velocity field within the enclosed space, the most one can hope for is a "best" guess.

Determining a precise value for the exchange factors is difficult although the principle behind them and their importance are easy to understand. In the extreme, $f_{ij}$ can be either zero, representing no air flow between slices as in the case of slices separated by impenetrable boundaries, or larger values approaching 10 that represent a great deal of air flow between two slices which essentially treats the slices as a continuous, well-mixed cell. An exchange factor with a value of unity can represent plug flow. The important point to remember is that exchange factors are a scalar multiples of the overall volumetric flow rate into and out of the tank and not percentages of that air flow. This is due to the fact

that there can be internal mixing within the control volume so vigorous that the volumetric flow rate between adjacent slices is greater than the overall volumetric flow rate into and out of the tank.

In this study the assumption was made that there was a well-mixed condition within each slice. Although this greatly simplified the analysis, it may not be true for ten equally sized slices. There is no limit to the number of slices which may be used in the SBM analysis of this or any problem. Taking a larger number of slices improves the method's accuracy but would also have required additional computational time and therefore increased cost. As in any other engineering problem, the cost to benefit ratio must be weighed in determining the solution.

To improve the selection method of the exchange factor, one could use a device to measure the concentration of a tracer gas within the occupied tank [30,31]. A more accurate prediction of the contaminant concentration within the tank as a function of time and space, could be found using various computer models to solve the conservation equations for fluid flow. For example, the following commercially known codes would apply: CHAMPION, FIDAP, FLOTRAN, FLOW3D, FLUENT, GENMIX, NEKTON, PHOENICS, TEACH, 3-D FLOW, AND 2/E/FIX [7].

The second objective, which was to evaluate the potential health hazard caused by this operation was covered in chapters 4, 6 and 7 through the determination of the Threshold Limit Values for each coating, the contaminant concentration as a function of time and the Exposure Parameter for each shift during the process.

Although a TLV can be determined for the liquid mixture and an Em can be determined for the vapors released, there is still no system in place to monitor the actual exposure of the workers to these contaminants. The best way to correlate and validate the results provided in Chapter 6 and the interpretations of those results, provided in Chapters 7 and 8, would be to conduct experiments leading to data regarding the actual contaminant concentration as a function of time and space; such as, placing monitors within different sections of the tank or requiring the workers to wear monitors. Without such tests, even an analysis, similar to that presented in this study, would provide management with an insight as to the severity of the hazard potential. This insight could be used as a tool or justification for modifying work schedules or practices.

The final objective in the study was to recommend ways to reduce the potential health hazard, if one existed. Because the Em for three out of five work-weeks in the process, as indicated in Table 8, the author concludes that there is indeed a potential health hazard. This hazard; however, is diminished by the use of personal protective equipment. The amount to which it is reduced is uncertain. Prudence and good judgment would dictate continuing the following practices:

1) monitor the workers' health with regard to the information provided on the MSDS's (i.e., reactions, allergies to chemicals within the paint, difficulty breathing, etc).

2) monitor the space the workers are occupying for volatile hydrocarbons using dosimeter badges.

3) use personal protective equipment throughout the process and ensure that it is changed as often as required by OSHA regulations.

To further reduce the potential risk it is suggested that the time between coats be reduced. This would diminish the hydrocarbon vapor the workers are continuously exposed to and thereby reduce the weekly average exposure levels and ultimately the exposure parameter.

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# APPENDIX A

NAVFAC GUIDE SPECIFICATION
09872
(OCTOBER 1987)

DEPARTMENT OF THE NAVY
NAVAL FACILITIES
ENGINEERING COMMAND
GUIDE SPECIFICATION

NFGS-09872 (October 1987)
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Superseding
NFGS-09872 (January 1983)

SECTION 09872

# INTERIOR COATING SYSTEMS USED ON WELDED STEEL TANKS (FOR PETROLEUM FUEL STORAGE)

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SECTION 09872

# INTERIOR COATING SYSTEMS USED ON WELDED STEEL TANKS (FOR PETROLEUM FUEL STORAGE) (A)

## PART 1 - GENERAL

1.1 APPLICABLE PUBLICATIONS: The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only. (B)

1.1.1 Military Specifications (Mil. Spec.):

| | |
|---|---|
| MIL-B-131G | Barrier Materials, Watervaporproof, Greaseproof, Flexible, Heat-Sealable |
| MIL-P-3420E & Am-2 | Packaging Materials, Volatile Corrosion Inhibitor Treated, Opaque |
| DOD-P-15328D & Am 1 | Primer (Wash), Pretreatment (Formula No. 117 for Metals) (Metric) |
| MIL-S-22262A | Abrasive Blasting Media--Ship Hull Blast Cleaning |

1.1.2 Department of Labor, Occupational Safety and Health Administration (OSHA) Standards:

| | |
|---|---|
| 29 CFR 1910.134 | Respiratory Protection |
| 29 CFR 1910.1000 | Subpart Z - Toxic and Hazardous Substances |
| 29 CFR 1910.1018 | Inorganic Arsenic |
| 29 CFR 1910.1025 | Lead |
| 29 CFR 1910.1200 | Hazard Communication |
| 40 CFR 260 | Hazardous Waste Management System: General |
| 40 CFR 261 | Identification and Listing of Hazardous Waste |
| 40 CFR 262 | Standards for Generators of Hazardous Waste |
| 40 CFR 263 | Standards for Transport of Hazardous Waste |

| | |
|---|---|
| 40 CFR 264 | Standard for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities |
| 40 CFR 265 | Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities |
| 40 CFR 266 | Standard for Management of Specific Hazardous Waste and Facilities |

1.1.3 American Society for Testing and Materials (ASTM) Publications:

| | |
|---|---|
| D 263-75 (R 1981) | Chrome Oxide Green Pigment |
| D 476-84 | Titanium Dioxide Pigments |
| D 478-86 | Zinc Yellow (Zinc Chromate) Pigments |

1.1.4 Steel Structures Painting Council (SSPC) Publications:

| | |
|---|---|
| PA 2-82 | Measurement of Dry Paint Thickness with Magnetic Gauges |
| SP 5-85 | White Metal Blast Cleaning |
| SP 7-85 | Brush-Off Blast Cleaning |
| VIS 1-67 | Pictorial Surface Preparation Standards for Painting Steel Surfaces |

1.2 SUBMITTALS: Submit the following to the Contracting Officer. (C)

1.2.1 Certificates of Conformance:| Before delivery of the coating system, submit [four] [_____] copies of certificates of comformance.

1.2.2 Samples:| Submit sample as specified in paragraph entitled "SAMPLING AND TESTING."

1.2.3 Formulator's Instructions:| Before application, submit three copies of formulator's printed instructions to include brand names, catalog numbers, and names of manufacturers. Include in the instructions detailed mixing and application procedures, number and types of coats required, minimum and maximum application temperatures, No. 2 Zahn cup values to be used for field checking of coating, and curing procedures.

1.2.4 Coating Materials Test Results:| Provide six copies of laboratory test results of coating materials in accordance with paragraph entitled "SAMPLING AND TESTING."

1.2.5 Blasting Abrasive Test Results:| Provide laboratory test results of blasting abrasive and certify conformance to contract requirements. Provide six copies of results of tests required by Mil. Spec. MIL-S-22262A and certifications.

1.2.6 Material Safety Data Sheets (MSDS):| Provide six copies of material safety data sheets for materials to be used at the job site in accordance with OSHA 1910.1200.

1.3 DELIVERY AND STORAGE: Urethane materials should be shipped and stored out of the sun and weather, preferably in air conditioned spaces.

1.4 SAFETY: The Contractor shall ensure that employees are trained in the requirements of OSHA 1910.1200 and understand the information contained in the MSDS for their protection against toxic and hazardous chemical effects.

1.5 [GOVERNMENT-FURNISHED MATERIALS AND SERVICES: The Government will furnish, without cost, all test fuel products for leakproof testing of coated tank as specified in the paragraph entitled "Final Inspection."] (D)

1.6 JOB SITE REFERENCES: The contractor shall have at least one copy each of SSPC SP 5, SSPC PA2, and SSPC VIS 1 at the job sit and made available to the Contracting Officer.

PART 2 - PRODUCTS

2.1 Organic Coating System: The polyurethane coating system consists of a pretreatment wash primer, a polyurethane primer, an intermediate coating, and a finish coating as specified below.

2.1.1 Wash Primer: Mil. Spec. DOD-P-15328.

2.1.2 Polyurethane Primer: Formulate as shown in Table I. Disperse the pigments used in Component A on a paint mill to a North Standard 4 on a Hegman gauge using as much of the solvent blend as required for a good working viscosity. Add any remaining solvent to the grind separately. Immediately prior to application, stir the required amount of Component B of Table I into the Component A. Add additional urethane grade solvents (anhydrous) to produce the optimum viscosity for application. Apply the combined components in less than 3 hours after mixing.

Table I. Composition of Polyurethane Primer

| Ingredient | Composition Pounds (Kilograms) | | Gallons |
|---|---|---|---|
| Component A | | | |
| DESMOPHEN 1100 polyester * | 188 | (85.3) | 20.0 |
| n-Butyl acetate (anhydrous) | 57 | (25.9) | 7.8 |
| Ethyl acetate (anhydrous) | 48 | (21.8) | 6.4 |
| Propylene glycol monomethyl ether acetate (urethane grade) | 32 | (14.5) | 4.0 |
| Toluene (anhydrous) | 24 | (10.9) | 3.3 |
| Zinc chromate (ASTM D 478, Type I or II) | 334 | (151.5) | 11.6 |
| Talc, micronized ** | 114 | (51.7) | 4.8 |
| Bentone 27 *** | 18 | (8.2) | 1.3 |
| Anti-Terra-U **** | 6 | (2.7) | 0.8 |
| | 821 | (372.5) | 60.0 |
| Component B (See "Note" below) | | | |
| Mondur CB-75 (75 percent nonvolatile isocyanate solution) * | 198 | (89.8) | 20.0 |
| n-Butyl acetate (anhydrous) | 52 | (23.6) | 7.1 |
| Ethyl acetate (anhydrous) | 45 | (20.4) | 6.0 |
| Propylene glycol monomethyl ether acetate (urethane grade) | 30 | (13.6) | 3.7 |
| Toluene (anhydrous) | 23 | (10.4) | 3.2 |
| Totals | 348 | (157.8) | 40.0 |

* Mobay Chemical Company, Pittsburgh, PA 15205
** Vanderbilt NYTAL 300, R. T. Vanderbilt, Inc., New York, NY
*** NL Industries, Inc., Industrial Chemical Division, P.O. Box 700, Hightstown, NJ 08520
**** Byk-Mallinckrodt Chemical Products GmbH, Melville, NY 11747

Note: Purge Component B with dry nitrogen before sealing container

2.1.3 **Polyurethane Intermediate Coat:** Formulate as specified in Table II and prepare the coat as specified for the primer in paragraph entitled "Polyurethane Primer."

Table II. Composition of Polyurethane Intermediate Coat

| Ingredient | Composition Pounds (Kilograms) | | Gallons |
|---|---|---|---|
| Component A | | | |
| DESMOPHEN 800 polyester * | 88 | (39.9) | 9.4 |
| DESMOPHEN 1100 polyester * | 88 | (39.9) | 9.4 |
| n-Butyl acetate (anhydrous) | 77 | (34.9) | 10.5 |
| Ethyl acetate (anhydrous) | 66 | (29.9) | 8.9 |
| Propylene glycol monomethyl ether acetate (urethane grade) | 44 | (20) | 5.4 |
| Toluene (anhydrous) | 33 | (15) | 4.5 |
| Chrome oxide green (ASTM D 263) *** | 188 | (85.3) | 4.4 |
| Titanium dioxide (Rutile) (ASTM D 476, Type IV) | 188 | (85.3) | 5.4 |
| Bentone 34** | 18 | (8.2) | 1.3 |
| Anti-Terra-U *** | 6 | (2.7) | 0.8 |
| | 796 | (361.1) | 60.0 |
| Component B (See "Note" below.) | | | |
| Mondur CB-75 (75 percent nonvolatile isocyanate)* | 262 | (118.8) | 26.4 |
| n-Butyl acetate (anhydrous) | 36 | (16.3) | 4.9 |
| Ethyl acetate (anhydrous) | 31 | (14.1) | 4.1 |
| Propylene glycol monomethyl ether acetate (urethane grade) | 21 | (9.5) | 2.6 |
| Toluene | 15 | (6.8) | 2.0 |
| Totals | 365 | (165.5) | 40.0 |

* Mobay Chemical Company, Pittsburgh, PA 15205

** NL Industries, Inc., Industrial Chemical Division, P.O. Box 700, Hightstown, NJ 08520

*** Byk-Mallinckrodt Chemical Products GmbH, Melville, NY 11747

Note: Purge Component B with dry nitrogen before sealing container.

2.1.4 Polyurethane Top Coat: Formulate as specified in Table III and prepare as specified for the primer in paragraph entitled "Polyurethane Primer."

Table III. Composition of Polyurethane Gloss, Top Coat

| Ingredient | Composition Pounds (Kilograms) | | Gallons |
|---|---|---|---|
| Component A | | | |
| DESMOPHEN 800 polyester * | 93 | (42.2) | 9.9 |
| DESMOPHEN 1100 polyester * | 93 | (42.2) | 9.9 |
| n-Butyl acetate (anhydrous) | 81 | (36.7) | 11.0 |
| Ethyl acetate (anhydrous) | 69 | (31.3) | 9.2 |
| Propylene glycol monomethyl ether acetate (urethane grade) | 46 | (20.9) | 5.7 |
| Toluene (anhydrous) | 34 | (15.4) | 4.7 |
| Titanium dioxide (Rutile) (ASTM D 476, Type IV) | 250 | (113.4) | 7.5 |
| Bentone 27 ** | 18 | (8.2) | 1.3 |
| Anti-Terra-U *** | 6 | (2.7) | 0.8 |
| | 690 | (313) | 60.0 |
| Component B (See "Note" below) | | | |
| Mondur CB-75 (75 percent nonvolatile isocyanate) * | 304 | (137.9) | 30.7 |
| n-Butyl acetate (anhydrous) | 24 | (10.9) | 3.3 |
| Ethyl acetate (anhydrous) | 21 | (9.5) | 2.8 |
| Propylene glycol monomethyl ether acetate (urethane grade) | 14 | (6.4) | 1.7 |
| Toluene (anhydrous) | 11 | (5) | 1.5 |
| Totals | 374 | (169.6) | 40.0 |

* Mobay Chemical Company, Pittsburgh, PA 15205
** NL Industries, Inc., Industrial Chemical Division, P.O. Box 700, Hightstown, NJ 08520
*** Byk-Mallinckrodt Chemical Products GmbH, Melville, NY 11747

Note: Purge Component B with dry nitrogen before sealing container.

2.2 Abrasive: (E)

2.2.1 Blasting Abrasive: Abrasive shall be sharp, washed, salt-free, angular, crushed wet bottom boiler slag or nickel slag, free from feldspar or other constituents that tend to break down and remain on the surface. Abrasive shall not contain magnetic materials and shall conform to Mil. Spec. MIL-S-22262A, Type I (Inorganic materials) except that Mohs' hardness shall be 7 to 9 [and _____].

2.2.2 Recycled Abrasive: Recycled abrasive at the job site shall be screened and air washed to remove dirt and fines. New abrasive shall then be added so that the combined new and recycled abrasive mixture shall meet all specified abrasive requirements for chemical composition, moisture, friability, silica, anchor pattern and oil content. Do not recycle abrasive which has picked up toxic or hazardous material. Nickel slag shall not be recycled.

2.2.3 Vaportight Material: Mil. Spec. MIL-B-131 or Mil. Spec. MIL-P-3420.

PART 3 - EXECUTION

3.1 PROTECTION FROM TOXIC AND HAZARDOUS CHEMICAL AGENTS: During tank cleaning, cleanup, surface preparation, and paint application phases, ensure that employees are adequately protected from toxic and hazardous chemical agents which exceed the concentrations in OSHA 1910.1000[, OSHA 1910.1018, and OSHA 1910.1025]. Comply with respiratory protection requirements in OSHA 1910.134. (F)

3.2 HANDLING OF COATING MATERIALS:

3.2.1 Mixing: Thirty minutes or more of mixing with a heavy duty shaker (5 hp) is required to mix Component A pigment before opening the can.

3.2.2 Boxing: When mixing components, "boxing" (pouring from can to can) is prohibited except one time to examine the bottom of Component A can to ensure all pigment has been mixed. Use a mixer that does not create a vortex. Mix out of the weather, preferably in dehumidified space. It is essential that no moisture or moist air be introduced to the mix.

3.2.3 Checking Viscosity: Zahn Cup shall be used in the field by the Contractor continually to check the viscosity of mixed coating components to assure that premature gelling is not occurring. The Contracting Officer will witness the test. Provide No. 2 Zahn cup. The Contractor shall obtain No. 2 Zahn cup reading values in seconds from the formulator of the coating to establish the limiting values to be used in the field.

3.2.4 Pot Life: Application (pot) life is always based on standard conditions at 70 degrees F (21 degrees C) and 50 percent relative humidity. For every 18 degrees F (10 degrees C) rise in temperature, application life is reduced by half, and for every 18 degrees F (10 degrees C) drop it is doubled. High humidity at the time of mixing and application also shortens application life. Precooling, or exterior icing, or both of mix material during application in hot climates will extend pot life.

3.3 PRELIMINARY INSPECTION: Prior to starting any work, verify that the tank and connecting lines have been emptied of fuel.

3.4 SAMPLING AND TESTING:

3.4.1 Sampling: Notify the Contracting Officer when the materials are available for sampling at the site or source of supply. Obtain a one-quart sample of each batch by random selection from the sealed containers. When directed, take samples in the presence of the Contracting Officer. Prior to sampling, mix contents of the sealed container to ensure uniformity. A batch is defined as that quantity of material processed by the manufacturer at one time and identified by number on the label. Clearly identify samples by designated name, specification number, batch number, project contract number, intended use, and quantity involved. These samples, or parts there of, not used in testing shall be retained for one year for examination in the event of premature failure of the coating. Shipping and testing of the samples shall be done by the Contractor.

3.4.2 Testing: Test samples to determine if they meet the requirements given in Table IV. If a sample fails to meet specification requirements, replace the material represented by the sample, and reselect and retest samples. Submit a copy of all test results to the Contracting Officer for approval. If the quantity of any one material to be used is under 50 gallons (189 liters), acceptance by the Contracting Officer may be based on certification, and testing of the sample representing that quantity need not be performed; however, take samples and hold in reserve when the need of testing arises. Tests shall be performed by an independent testing laboratory approved by the Contracting Officer at the expense of the Contractor.

3.5 VENTILATION: Provide ventilation inside tanks throughout course of work as required to maintain a vapor-free condition. Use exhaust fans, either explosion-proof electrically operated or air-driven. Fans shall have sufficient capacity to hold vapor concentration below 4 percent of lower explosive limit as determined with an approved explosive meter. Keep fans in operation whenever workmen are in tanks and as long as may be necessary for proper application and curing of coatings. Ventilation shall meet at least minimum safety requirements appropriate to thinners or chemicals used. During application of the coating system, provide a minimum of 10 air changes per hour. Where this is not feasible due to size of tank or limitations in number and size of manhole openings, then provide suction ductwork extending to areas of heaviest concentrations including lowest levels of tank. In no case shall exhaust fan capacity be less than 10,000 CFM except for small tanks of 250,000 gallons capacity or less. Ventilate tanks thoroughly during abrasive blasting and during application and curing of coating. Provide heating, cooling, or dehumidification if required to satisfy conditions specified in paragraph entitled "Temperature Conditions."

3.5.1 Health: All operations shall be reviewed and approved by an industrial hygienist as to correctness of work procedures and personal protective equipment. The services of the industrial hygienist shall be obtained by the Contractor.

Table IVa - Quality Control Test Ranges, Primer

| | Component A | | Mixture A&B | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max. |
| Viscosity, Krebs Units | 115 | 121 | 61 | 67 |
| Pigment, percent by weight | 48 | 52 | 39.7 | 43.7 |
| Volatiles, percent by weight | 29.2 | 33.2 | 28.2 | 32.2 |
| Nonvolatiles, percent by weight | 66.8 | 70.8 | 67.8 | 71.8 |
| Weight per gallon, lbs. | 12.3 | 12.7 | 11.8 | 12.2 |
| Drying time, hrs., tack-free | ---- | ---- | ---- | 2.5 |
| Flash point, Degrees F (Degrees C) Tag (Open Cup) (TOC) | ---- | ---- | 30 (-1) | ---- |

Table IVb - Quality Control Test Ranges, Intermediate Coat

| | Component A | | Mixture A&B | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max. |
| Viscosity, Krebs Units | 77 | 83 | 61 | 67 |
| Pigment, percent by weight | 45.2 | 49.2 | 30.4 | 34.4 |
| Volatiles, percent by weight | 25.6 | 29.6 | 31.5 | 35.5 |
| Nonvolatiles, percent by weight | 70.4 | 74.4 | 64.5 | 68.5 |
| Weight per gallon, lbs. | 13.1 | 13.5 | 11.4 | 11.8 |
| Drying time, hrs., tack-free | ---- | ---- | ---- | 7 |
| Flash point, Degrees F (Degrees C), TOC | ---- | ---- | 30 (-1) | ---- |

Table IVc - Quality Control Test Ranges, Top Coat

| | Component A | | Mixture A&B | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max. |
| Viscosity, Krebs Units | 66 | 72 | 61 | 67 |
| Pigment, percent by weight | 34.2 | 38.2 | 21.5 | 25.5 |
| Volatiles, percent by weight | 31.3 | 35.3 | 33.3 | 37.3 |
| Nonvolatiles, percent by weight | 64.7 | 68.7 | 62.7 | 66.7 |
| Weight per gallon, lbs. | 11.3 | 11.7 | 10.4 | 10.8 |
| Drying time, hrs., tack-free | ---- | ---- | ---- | 5 |
| Flash point, Degrees F (Degrees C), TOC | ---- | ---- | 30 (-1) | ---- |

3.6 TANK CLEANING, SAFETY, AND FUEL REMOVAL: Cleaning of storage tanks, including ventilation, fuel removal, and safety, shall be in accordance with Section titled "Cleaning Petroleum Storage Tanks."

3.7 SURFACE PREPARATION: [Tanks to be coated are existing tanks, and waste disposal of products, including sludge, contaminated blasting grit, water, and the like, shall be done in accordance with the paragraph entitled "TANK CLEANING, SAFETY, AND FUEL REMOVAL."] (G)

3.7.1 Equipment: Use blasting equipment of the conventional air, force-feed, or pressure type. No water blasting or vapor blasting will be permitted in order to keep steel surfaces moisture-free. Use a nozzle of such size that a pressure of 90 plus or minus 10 psig (621 plus or minus 69 kPa) will be maintained at the nozzle. Filter air supply so that the air is free of oil and moisture. Blow the compressed air through a clean white cloth to check for oil and moisture.

3.7.2 Clean and Repair: Brush-off blast clean surfaces to receive organic coating in accordance with SSPC SP 7. After blasting, remove all abrasive and dust from the surfaces by brushing, blowing with dry compressed air, and vacuuming, and then remove all loose material from the tank interior. Carefully examine the tank interior for defects. Test all bottom weld seams and suspect areas with a vacuum box. Use a glass top vacuum box with Hypalon or neoprene sealing gasket. Apply a commercial bubble forming solution to the weld or area to be tested; position the vacuum box over the area and slowly pull a partial vacuum. Carefully observe the solution film for bubble formation between 0-2 psi (0-14 kPa) differential pressure. Continue to open the valve until a differential pressure of 5 psi (34 kPa) is achieved and hold for at least 20 seconds while continuing to observe the solution for bubbles. Repair defects found, such as cracks or splits, by welding. Grind off rough surfaces on weld seams, sharp edges, and corners to a radius of not less than 1/8 inch (3 mm).

3.7.3 Abrasive Blast:

3.7.3.1 Surface Standard: Inspect the tank walls and select plate with similar characteristics and surface profile for use as a surface standard. White blast clean one or more foot-square steel panels in accordance with SSPC SP 5. White metal blast surfaces shall conform to SSPC VIS 1. Record the blast nozzle type and size, air pressure at the nozzle or compressor, distance of nozzle from the panel, and angle of blast to establish procedures for blast cleaning to develop a one- to 2-mil (25.4 to 50.8 micron) anchor pattern. Use a surface profile comparator, appropriate to the abrasive being used, to determine the profile of the standard panel before and after the white blast. A Keane-Tator surface profile comparator to determine the anchor pattern has been found useful. Keep the surface standard wrapped and sealed in vapor tight material for use as a standard of comparison for the steel surfaces throughout the course of the work.

3.7.3.2 Preparation: Abrasive blast steel surfaces to white metal in accordance with SSPC SP 5 as described in and as determined by the paragraph entitled "Surface Standard." Blast surfaces in sections or blocks small enough to permit application of the organic coating system during the same work shift. After blasting, remove all abrasive and dust from the surfaces by brushing and vacuuming. Remove all loose material from the tank interior. Fill all voids, pits, sharp depressions, or other imperfections by welding as approved by the Contracting Officer. Apply application of pretreatment wash primer within 8 hours of blasting. Inspect the blasted surfaces with black light to check for fluorescence from compressor oil. Surfaces to receive coating shall be free of oil.

3.7.3.3 Disposal of Used Abrasive: Test used abrasive in accordance with OSHA Part 261 to determine if it is a hazardous waste using the EP toxicity test for metals. Handle and dispose of abrasive determined to be hazardous waste in accordance with OSHA Parts 260 through 266. Dispose of abrasive which is not hazardous waste at a landfill off Government property in accordance with applicable regulations. The contract price will be adjusted if the used abrasive is determined to be hazardous waste. However, payment for disposal of hazardous waste will not be made until a completed manifest from the treatment or disposal facility is returned, and a copy furnished to the Government.

3.8 TEMPERATURE CONDITIONS: Abrasive blast and coat only when the steel surface temperature is more than 5 degrees F (3 degrees C) above the dew point temperature of the surrounding air. This 5 degrees F (3 degrees C) differential is necessary to prevent condensation of moisture on the tank surface. Accomplish coating application when the ambient air and steel surface temperature are between 50 and 90 degrees F (10 and 32 degrees C).

3.9 APPLICATION OF COATING SYSTEM: During coating application, ground all (H)
nozzles and metallic components against static discharges, and provide adequate ventilation. Surfaces to receive coating shall be free of dust, dirt, oil, and other contaminants as determined by visual examination. Use clean canvas shoe covers when walking on prepared surfaces ready to receive coating and on coated surfaces. Apply organic coating system on tank bottom, side-wall, and columns. Coat the tank interior, including floor [and side-walls] [, side-walls, ceiling, and all structural steel members] [and side-wall to not less than 18 inches (457 mm) above the tank bottom]. [Aluminum floating [roof] [pan] shall not be coated.] Contractor shall sequence work so that urethane coating is not flooded with water for more than 24 hours nor prior to curing urethane for not less than 2 weeks [and only to set the high legs to do last (bottom) portion]. Top-down application is required. Apply coatings in laps as shown on the drawings. Apply the wash primer as soon as possible after the blast cleaning, but in no case shall the time interval exceed 8 hours. If visible rusting does occur after blasting, regardless of the time interval, reblast the rusted surface prior to applying the required primer. Coat all interior steel surfaces of the tank including the bottom; shell; ceiling or underside of floating roof, where applicable; all internal piping; roof legs, where applicable; other internal,

structural-steel and appurtenances. Use experienced applicators. Rollers will not be permitted. Apply the polyurethane coating system as follows: Coat all surfaces with the wash primer base coat. Apply wash primer to a dry film thickness of between 0.3 to 0.5 mil (8 to 13 microns). Apply the wash primer within 8 hours after mixing and within 8 hours after the blast cleaning. Discard wash primer not used within 8 hours after mixing. Apply two coats of polyurethane primer over all corners, crevices, and welds. Apply the additional coat of primer by brush, working the material into corners, crevices, and welds, and onto outside corners and angles after the general application of the polyurethane primer coat. Apply this polyurethane primer coat not sooner than one-half hour nor later than 8 hours after application of the wash primer. Apply the polyurethane intermediate and top coats successively, allowing a drying time of not less than 8 hours nor more than 48 hours between each coat. Apply each of the coats so as to obtain a dry film thickness of approximately 2 mils (51 microns) for each coat and a total dry film thickness not less than 6 mils (152 microns) for the complete system. Apply an additional top coat, if necessary, to obtain the required minimum thickness of 6 mils (152 microns).

3.10 FIELD TESTS AND INSPECTIONS:

3.10.1 General: Use clean canvas shoe covers when walking on coated surfaces. Advise the Contracting Officer when the work in progress is at the following steps so that appropriate inspection may be made:

| Step | Action |
|---|---|
| Prior to preparation of tank(s) for cleaning and repair | Safety inspection |
| After cleaning of tank(s) and prior to abrasive blasting | Safety inspection, removal of dirt, trash debris, and any hindrance to abrasive blasting |
| After abrasive blasting | Surface inspection for appropriate finish for coating application as specified in the paragraph entitled "APPLICATION OF COATING SYSTEM" |

| Step | Action |
|---|---|
| During and after coating application | Coating application inspection as specified in paragraphs entitled "APPLICATION OF COATING SYSTEM" and "Final Inspection" |
| After final cleanup | Cleanup inspection specified in the paragraph entitled "FINAL CLEANUP" |

3.10.2 Final Inspection:

3.10.2.1 Thickness: Following completion and cure of the coating system, inspect the surfaces for pinholes, blisters, inadequate coating thickness, and other defects. Repair all imperfections found. Measure the dry film thickness in accordance with SSPC PA 2 at 10 equally spaced points within a 10-foot by 10-foot (3-m by 3-m) area as designated by the Contracting Officer. Discard the high and low values, and average the remaining eight values as the coating thickness. If the average is less than the specified minimum dry film thickness, take additional readings in adjacent areas to define the extent of the thin area. Recoat such areas with the polyurethane top coat, as necessary, to achieve the specified thickness. Recoat within the time period specified in the paragraph entitled "APPLICATION OF COATING SYSTEM." Lightly brush blast or hand sand any coated areas that exceed 48 hours to remove the glossy surface before applying the additional top coat.

3.10.3 Fill Test: After the work has been inspected and approved, fill test the tank. Allow a cure time of at least 14 days after the final coat has been applied before carrying out the fill test. Remove the blind flanges and reconnect all tank piping ready for service. Reinstall the liquid level gauging float. The Government will provide the necessary fuel and labor to fill the tank with fuel. Advise the Contracting Officer, in writing, at least 10 days in advance of the need for this service. Fill tank half full and check that all drain valves are closed and check tank for leaks. Keep tank half full the first 12 hours of test, then fill tank to full capacity, and check that all drain valves are closed and check tank for leaks. Monitor tank level hourly during the first 24 hours of the fill test and notify the Contracting Officer immediately of any leaks detected. Padlock drain valves closed for the duration of the test and provide one set of keys to the Contracting Officer. After the temperature of the fuel has become stabilized, take daily readings of the fuel level for a period of 10 days. If there is no measurable drop in the fuel level during this period, the tank will be accepted. If leakage becomes apparent during the filling or the test period, immediately notify the Contracting Officer and Government personnel will pump the fuel from the tank. Free the tank of vapor, clean it, and then carefully inspect the new coating system for evidence of failures. Repair all defects found and repeat fill tests.

3.11 FINAL CLEANUP: Following completion of the work, remove all debris, equipment, and materials from the site. Remove temporary connections to Government furnished water and electrical services. Restore all existing facilities in and around the work areas to their original condition.

*** END OF SECTION *** (I)

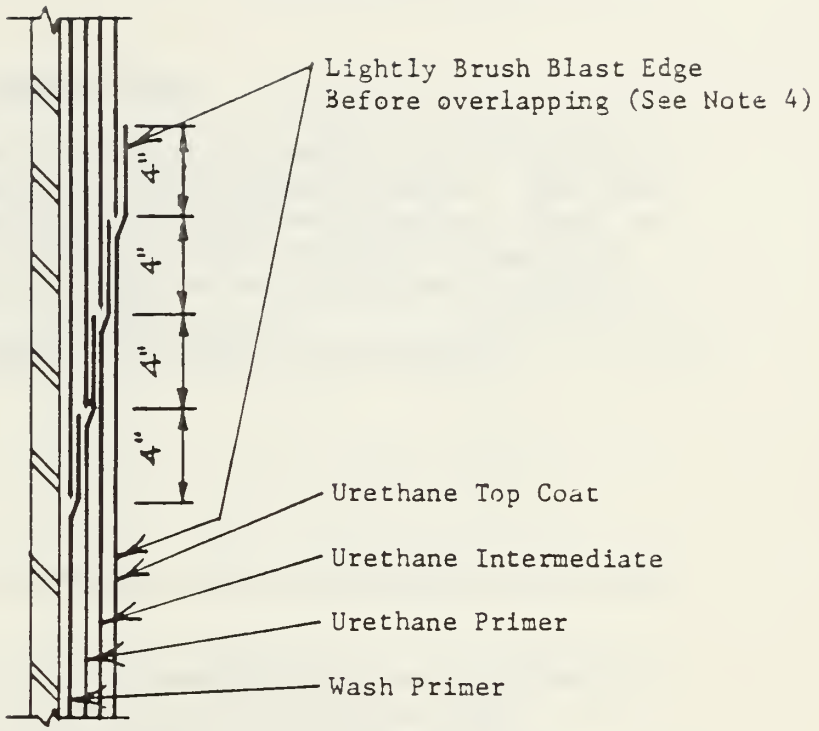
NOTES

1. No lap joints over welds.

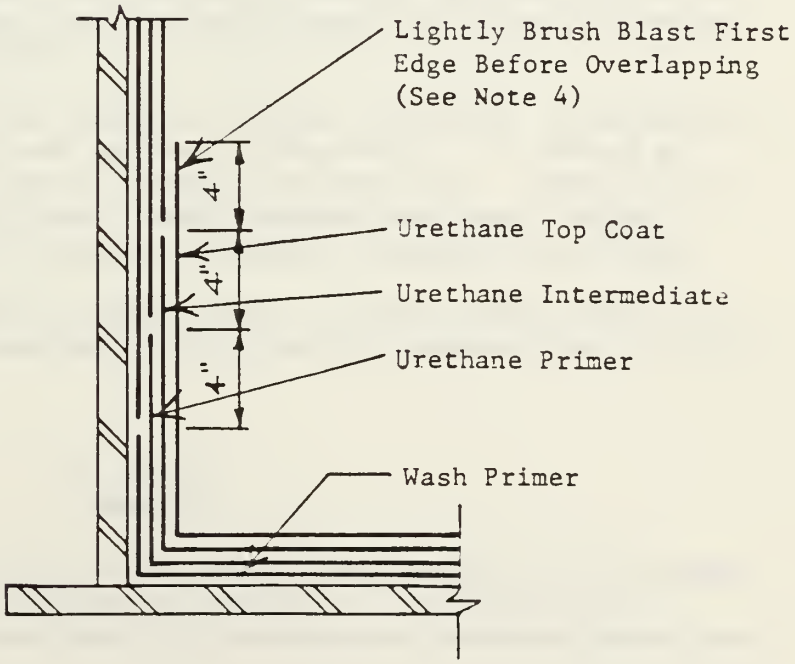
2. Coat ceiling and shell first.

3. When only coating bottom and up 18 inches, coat shell and bottom simultaneously.

4. Light brush blast of edge required only when maximum drying time between coatings has been exceeded.




SHELL OR TANK CEILING




SHELL TO BOTTOM

Sketch 09872-1

GENERAL NOTES

1. Do not refer to this guide specification in the project specification. Use it as a manuscript to prepare the project specifications. Edit and modify this guide specification to meet project requirements. Where "as shown," "as indicated," "as detailed," or words of similar import are used, include all requirements so designated on the project drawings.

2. Do not include the following parts of this NFGS in the project specification:

    a. Table of Contents.
    b. Sketches.
    c. General Notes.
    d. Technical Notes.
    e. Other supplemental information, if any, attached to this guide specification.

    As the first step in editing this guide specification for inclusion in a project specification, detach all parts listed above and, where applicable, use them in the editing process. If required in the construction contract, sketches and figures shall be placed on the project drawings. Where there are no project drawings, sketches and figures may be included as a part of the project specification, if required.

3. Each capital letter in the right-hand margin of the text indicates that there is a technical note pertaining to that portion of the guide specification. Do not include these letters in the project specification. If this is a regionally tailored version of this NFGS, i.e., an EFD Regional Criteria Master, some technical notes and their designating letters may have been deleted.

4. Where numbers, symbols, words, phrases, clauses, sentences, or paragraphs in this guide specification are enclosed in brackets, [], a choice or modification must be made; delete inapplicable portion(s). Where blank spaces enclosed in brackets occur, insert appropriate data. Delete inapplicable paragraphs and renumber subsequent paragraphs accordingly.

5. Project specification number, section number, and page numbers shall be centered at the bottom of each page of the section created from this guide specification.

    EXAMPLE:

    05-87-1987
    09872-1

6. CAUTION: Coordination of this section with other sections of the project specification and with the drawings is mandatory. If materials or equipment are to be furnished under this section and installed under other

sections or are indicated on the drawings, state that fact clearly for each type of material and item of equipment. Review the entire project specification and drawings to ensure that language is included to provide complete and operational systems and equipment.

7. Specifications shall not repeat information shown on the drawings. Specifications shall establish the quality of materials and workmanship, methods of installation, equipment functions, and testing required for the project. Drawings shall indicate dimensions of construction, relationship of materials, quantities, and location and capacity of equipment.

8. The following information shall be shown on the project drawings:

   The following information shall be shown on the project drawings:

   a. Tank in plan and elevation including major appurtenances.

   b. Interior details to show Contractor complexity of work involved.

   c. Welds to be ground and other repair work. For indefinite repairs, consider unit price or requirements type of bid items.

   d. Coating application details. See Sketch 09872-1. Do not put sketch in specification section.

9. Suggestions for improvement of this specification will be welcomed. Complete the attached DD Form 1426 and mail the original to:

   COMMANDER
   Pacific Division, Code 406C
   Naval Facilities Engineering Command
   Pearl Harbor, HI 96890-7300

   Mail a copy to:

   COMMANDER
   Naval Facilities Engineering Command
   Code DS02
   200 Stovall Street
   Alexandria, VA 22332-2300

## TECHNICAL NOTES

A. This guide specification is intended to be used in specifying the requirements for coating systems for the interior of welded steel tanks used for petroleum storage. Options are given for the selection of coating the entire tank interior or just coating the bottom and side-wall to the nominal 18-inch (457-mm) height when funds are short. This

specification should not be used for tanks where there is severe general corrosion (metal thickness less than 1/8-inch (3-mm)) or where there are numerous holes all the way through the steel plate. Such tanks will require more extensive repairs such as patching or replacement of the steel bottom or installation of a fiberglass reinforced lining system which is described in Section 13661, "Fiberglass Reinforced Plastic Lining System for Bottoms of Steel Tanks (for Petroleum Fuel Storage)." This revision continues deletion of metallizing the bottom and side wall of the tank effected by the previous limited revision.

B. Paragraph 1.1: The latest issue of applicable publications shall be used, but only after reviewing the latest issue to ensure that it will satisfy the minimum essential requirements of the project. If the latest issue of a referenced publication does not satisfy project requirements:

1. Use the issue shown; or
2. Select and refer to a document which does; or
3. Incorporate the pertinent requirements from the document into the project specification.

Use DD Form 1426 to inform the Preparing Activity and NAVFACENGCOM if the latest issue of a referenced publication is not compatible with this guide specification.

Delete those publications not referred to in the text of the section created from this guide specification.

C. Paragraph 1.2: Editing should include the following considerations:

1. In projects using the Contractor Quality Control System, add the words, "Submit to the Contracting Officer.", at submittals deemed sufficiently critical or complex or aesthetically significant to merit approval by the Government.

2. Do not include the vertical bars in the final manuscript of the project specification. (Project Submittals Lists may be extracted from project specifications prepared on NAVFAC-programmed word processors. Vertical bars indicate points at which automatically extracted entries will terminate.)

D. Paragraph 1.4: The Contracting Officer will determine when the Government materials and services will be provided.

E. Paragraph 2.2: Revise specifications for abrasive, if necessary to meet local requirements.

F. Paragraph 3.1: Include OSHA 1910.1018 for arsenic exposure and OSHA 1910.1025 for lead exposure.

G. Paragraph 3.7: Provisions for disposal of waste products including contaminated blasting grits should be made by the Contractor as provided in the paragraph entitled "Tank Cleaning, Safety, and Fuel Removal" and as specified in paragraph entitled, "Disposal of Used Abrasive."

H. Paragraph 3.9: When funds are limited, existing bulk storage tanks can be coated on the floor and up the side-walls to a height of 18 plus or minus 2 inches. Edit paragraph to suit tank to be coated. Delete references to floating roofs or pans and setting of legs, if not applicable.

I. Following the text, not less than two nor more than six lines below the last line of text, insert *** END OF SECTION *** centered on the page.

*** E N D ***

# APPENDIX B

NAVFAC GUIDE SPECIFICATION
13219
(FEBRUARY 1988)

DEPARTMENT OF THE NAVY
NAVAL FACILITIES
ENGINEERING COMMAND
GUIDE SPECIFICATION

NFGS-13219 (February 1988)
---
Superseding
NFGS-13657 (March 1983)

SECTION 13219

CLEANING PETROLEUM STORAGE TANKS

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*Preparing Activity: Pacific Division

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SECTION 13219

# CLEANING PETROLEUM STORAGE TANKS (A)

## PART 1 - GENERAL

1.1 APPLICABLE PUBLICATIONS: The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only. (B)

1.1.1 Federal Specifications (Fed. Spec.):

| | |
|---|---|
| O-D-1276B | Disinfectant-Detergent , General Purpose (Pine Oil) |
| TT-T-291F & Int Am-1 | Thinner, Paint, Mineral Spirits, Regular and Odorless |

1.1.2 Military Specification (Mil. Spec.):

| | |
|---|---|
| MIL-A-22262A | Abrasive Blasting Media Ship Hull Blast Cleaning |

1.1.3 Code of Federal Regulations (CFR) Publications:

| | |
|---|---|
| 29 CFR 1910.134 | Respiratory Protection |
| 29 CFR 1910.1200 | Hazard Communication |
| 40 CFR 260 | Hazardous Waste Management System: General |
| 40 CFR 261 | Identification and Listing of Hazardous Waste |
| 40 CFR 262 | Standards for Generators of Hazardous Waste |
| 40 CFR 263 | Standards for Transport of Hazardous Waste |
| 40 CFR 264 | Standard for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities |
| 40 CFR 265 | Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities |
| 40 CFR 266 | Standard for Management of Specific Hazardous Waste and Facilities |

1.1.4 American National Standards Institute (ANSI) Publication:

| | |
|---|---|
| Z88.2-80 | Practices for Respiratory Protection |

1.1.5 American Petroleum Institute (API) Publications:

| | |
|---|---|
| RP 500C-84 | Recommended Practice for Classification of Locations for Electrical Installations at Pipeline Transportation Facilities |
| RP 2003-82 | Recommended Practice for Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents |
| PUBL 2015-85 | Cleaning Petroleum Storage Tanks |
| PUBL 2015A-82 | A Guide for Controlling the Lead Hazard Associated with Tank Entry and Cleaning. |
| PUBL 2015B-81 | Cleaning Open-Top and Covered Floating Roof Tanks |

1.1.6 National Fire Protection Association (NFPA) Publication:

| | |
|---|---|
| NFPA 70-87 | National Electrical Code |

1.1.7 Underwriters Laboratories Inc. (UL) Publication:

| | |
|---|---|
| 844-84 | Electric Lighting Fixtures for Use in Hazardous Locations |

1.1.8 National Institute for Occupational Safety and Health (NIOSH):

NIOSH Certified Personnel Protective Equipment List Current Issue

1.2 SUBMITTALS: (C)

1.2.1 Manufacturer's Data:|

1.2.1.1 Product Data:| Identify the following items by designated name, specification number, project contracting number, and intended use:

a. Cleaning Agents|

b. Gasoline-Oil-resisting Rubber Gloves and Boots|

c. Cotton Coveralls & Hard Hat|

d. Respiratory Protective Equipment|

e. Disinfectant.|

1.2.1.2 Material Safety Data Sheets (MSDS):| Provide six copies of material safety data sheets for materials to be used at the job site in accordance with 29 CFR 1910.1200.

1.2.2 Certificates of Conformance:|

1.2.2.1 Materials:| Where equipment or materials are specified to conform with the standards of organizations, such as National Institute for Occupational Safety and Health (NIOSH), Underwriters Laboratories (UL), and American Petroleum Institute (API), submit for approval a label or listing indicating compliance. In lieu of the label or listing, the Contractor may submit a certificate from an approved testing organization stating that the item has been tested in accordance with the specified organization's test methods and that the item conforms with the organization's standard or code. Submit seven copies of the certificates for the following items:

a. Respiratory Protective Equipment and Oil-Resistant, Wire-Reinforced Air Hose|

b. Breathing-Air Supply Source|

c. Gas Meter: Explosive Gas Meter[, Lead-in Air Analyzer] [, Hydrogen-Sulfide ($H_2S$) Indicator] and oxygen meter|

d. Lighting|

e. First Aid Kit|

f. Tank Exhaust Blower.|

1.2.2.2 Transporters, Treaters, Accumulators, Storers and Disposers:| Submit certification of EPA Identification number.

1.2.2.3 Tank: Submit certification, from an NFPA certified "Marine Chemist" [or "Gas Free Engineer"] stating that tank is safe for hot work and that special precautionary measures have been taken for workers to enter the tank to perform the work.

1.2.3 Laboratory Test Reports:| Submit six copies of certified laboratory test results required by Mil. Spec. MIL-A-22262, for blasting abrasive.

1.2.4 Schedule of Work:| The shut down or interruption to normal operations or traffic shall be listed on the progress schedule and submitted to the Contracting Officer for approval. (D)

1.2.5 Safety Program:| Prepare safety plan and submit within 45 calendar days after contract award and 30 days prior to commencing work. [The safety program shall be reviewed and approved by the safety/health officer of the facility.] The safety plan shall meet OSHA requirements and address the

following:

a. Identification and evaluation of the hazards and risks associated with each site being studied, including precautionary measures to be followed by workers.

b. Provide the names and qualifications of each Contractor's representative in charge of the work and present at the job site when tank cleaning and repair work are being performed. Permit only assigned personnel within 100 feet of the tank perimeter.

c. Identification of supervisory personnel and alternates responsible for site safety/response operations.

d. Determination of levels of personnel protection to be worn for various site operations.

e. Provide a complete list of equipment with adequate nomenclature by item, that will be used at the job site and the date and location where this equipment can be inspected by the Contracting Officer.

f. Provide four copies of API RPs 500C and 2003, API PUBLs 2015 [, 2015A] [and] [2015B]. (E)

g. Establishment of work zones (exclusion area, contamination area, and support area).

h. Establishment of decontamination methods and procedures.

i. Determination of the number of people required to enter the contamination zones during the initial entries and subsequent operations.

j. Establishment of emergency procedures, such as: escape routes, fire protection, signals for withdrawing work parties from site, emergency communications, wind indicators, including Navy notification.

k. Identification and arrangements with nearest medical facility for emergency medical care for both routine-type injuries and toxicological problems. Provide name, location, and telephone number of this medical facility.

l. Establishment of continual air and personnel monitoring procedures.

m. Establishment of procedures for obtaining and handling potentially contaminated samples.

n. Acquisition of safety permits (specified by the facility safety authorities) and necessary safety equipment.

o. Identification of medical monitoring program, including respirator

medical qualification examination for each individual at the work site.

p. Identification of training plan to be instituted, including contents of 29 CFR 1910.1200 and 29 CFR 1910.134; its training contents; and instructor with appropriate qualifications.

q. Establishment of a respiratory protection program conforming to 29 CFR 1910.134 and ANSI Z88.2.

r. Establishment of a hazard communication program (29 CFR 1910.1200).

1.2.6 Local, State, and Federal Permits:| Furnish copies of permits required to comply with local, state, and federal regulations.

1.2.6.1 For Hazardous Waste: Furnish copies of [EPA] [State] [and] [Local] hazardous waste [permit applications] [permits] [and] [EPA Indentification numbers] of the transporter, treatment, storage and disposal facility that will be accepting hazardous waste. Include the facility location and a 24-hour point or contact. (F)

1.2.6.2 For Non-hazardous Waste: Furnish [EPA] [State] [Local] permits for disposal site for non-hazardous residues and wastes.

1.3 QUALITY ASSURANCE: Except as modified herein, the work shall conform with the recommendations of API RPs 500C and 2003, API PUBLs 2015 [, 2015A] [and] [2015B]. Where the word "should" appears in these publications, substitute "shall." (E)

1.4 REGULATORY REQUIREMENTS: Obtain permits required to comply with local state, and federal regulations.

1.5 DELIVERY AND STORAGE: Deliver equipment and materials to the site in an undamaged condition bearing the manufacturer's name and brand designation. Store equipment and materials off the ground to provide proper ventilation, drainage, and protection against dampness. Replace defective and damaged equipment and materials.

1.6 JOB CONDITIONS:

1.6.1 Safety: Ensure that employees are trained in the requirements of 29 CFR 1910.1200 and understand the information contained in the MSDS for protection against toxic and hazardous chemical effects.

1.6.2 Ventilation: Maintain a vapor-free condition throughout the course of the work inside the tank. The air movers shall be non-sparking, explosion-proof, electrically operated or air-driven exhaust type. A rate of one air change per hour shall be the lowest acceptable rate, for tanks under 30,000 BBL. For tanks greater than 30,000 BBL, use 10,000 cfm. Air movers shall be kept in operation whenever workers are in the tanks; except the air movers shall be shut down 15 minutes before taking tests.

1.7 SCHEDULING AND SEQUENCING:

1.7.1 Sequence of Primary Phases of the Cleaning Procedure:

a. Planning the Operations

b. Prepartion for Cleaning

c. Vapor-Freeing of the Tank

d. Cleaning the Tank

e. Clean-up, Residue Disposal, Inspection, and Acceptance.

1.7.2 General Scheduling: Complete the work specified in this section before any other work in the tank is started. The work includes the complete interior cleaning of the storage tanks.

PART 2 - PRODUCTS

2.1 MATERIALS:

2.1.1 Cleaning Agents: (G)

a. Detergent: Fed. Spec. O-D-1276.

b. Solvent: Fed. Spec. TT-T-291, Type II, minimum flashpoint of 60 degrees C.

c. Approved commercial cleaning agent.

2.1.2 Abrasive:

2.1.2.1 Abrasive for Blasting: Provide sharp, washed, salt-free [, angular] abrasive material, free from feldspar and other constituents that tend to break down and remain on the surface. Abrasive shall not contain magnetic materials and shall conform to Mil. Spec. MIL-A-22262, Type I (Inorganic materials)[, except that Mohs' hardness shall be 7 to 9] [and [_____]].

2.1.2.2 Recycled Abrasive: Screen and air wash abrasive that is recycled at the job site, to remove dirt and fines. Add new abrasive so that the combined new and recycled abrasive mixture meets specified abrasive requirements for chemical composition, moisture, friability, silica, anchor pattern and oil content. Do not recycle abrasive which has picked up toxic or hazardous material. Do not recycle nickel slag.

2.2 EQUIPMENT: Furnish necessary clothing and equipment for the work and protection of people entering the tank. Electrical equipment and wiring shall be in accordance with NFPA 70, Class 1, Group D, Division 1. Provide

any item or items for the protection of these people including but not limited to the following:

a. Gasoline-Oil-Resisting Rubber Gloves and Boots: Gauntlet type and conductive type respectively (acid-proof rubber is an acceptable material); furnished for each person entering or working inside the tank or handling sludge materials on the exterior of the tank, plus one extra pair each for emergency use.

b. Cotton Coveralls and Hard Hat: Light colored; one change per person per day, and an adequate supply of chemical-resistant disposable coveralls to be worn over cotton coveralls.

c. Respiratory Protection: Provide one of the following types of NIOSH-approved respiratory protective equipment for each person working inside the tank, plus one extra for emergency use.

(1) Self-contained breathing apparatus with a full facepiece operated in a positive pressure mode.

(2) A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in a positive pressure mode and an auxiliary positive pressure self-contained breathing apparatus. [Provide and use two-way communication equipment when cleaning underground tanks [larger than 50,000 gallons capacity] [or] [where manhole accesses are deeper than 10 feet from the working level.]]

d. Safety Harness: For each person working inside tank, plus one extra for outside the tank.

e. One-half-Inch Diameter Life Rope of Required Length: For each person working inside the tank.

f. One-Inch Oil-Resistant Wire-Reinforced Air Hose of Required Length for Each Hose Mask: NIOSH approved; low-pressure type; part of manufacturer's mask and hose assembly.

g. Breathing-Air Supply Source: 29 CFR 1910.134.

h. Gas Meter (1.4 to 7.6 Percent Vapor by Volume) [, Lead-in Air Analyser (Up to 10 ppm)] [, Hydrogen-Sulfide ($H_2S$) (Up to 20 ppm) Indicator] [, Benzene Indicator (Up to 20 ppm)] and Oxygen Meter (Up to 21 percent by Volume).

i. Shovels, Buckets, Brooms, Wrenches, Scrapers, Squeegees, Wire Brushes, Scrub-Brushes, Ladders, Staging, and Other Tools: Do not use brooms or brushes that have plastic or synthetic bristles.

j. Lighting: UL 844, explosion-proof, minimum 50 footcandle, floodlight type, or Mining Enforcement and Safety Administration (MESA)

approved, explosion-proof, portable battery-powered light.

k. Air Movers for Tank Ventilation: Explosion proof electrically operated or air driven. Nonferrous fan blades.

l. Disinfectant for Cleaning Face Masks: Cleaner-sanitizer for cleaning and disinfecting respirator facepieces as specified in ANSI Z88.2.

m. Soap for Personnel Washing: Non-phosphate type.

n. A.B.C. Fire Extinguishers: UL listed 2A: 40B: C, 2A: 20B: C, or 4A: 30B: C; minimum 15 pound capacity.

o. First Aid Kit: One 16-unit kit for each 25 persons.

PART 3 - EXECUTION

3.1 PROJECT CONDITIONS:

3.1.1 Permission for Entry Into A Tank: Obtain written permission from the Contracting Officer prior to each entry into a tank. Permission will be granted only under the following conditions:

a. The Contractor's qualified supervisor is present.

b. The Contractor's personnel have been briefed by the supervisor on the procedure and role of each employee in the event of an emergency.

c. Required equipment is approved and properly located.

d. Personnel are properly equipped with properly fitted protective equipment and have received adequate training from a qualified instructor.

e. The entire area adjacent to the tank has been secured.

f. A minimum of two persons outside and two or more persons inside of each tank are provided at all times during cleaning operations.

g. Tank air is monitored and corrective action is taken to ensure that the vapor concentration is less than 4 percent of the lower flammable limit (LFL) [, lead-in-air is less than 0.075 milligrams per cubic meter at 4 percent LFL vapor concentration] [, hydrogen sulfide is less than 10 ppm permissible exposure level (PEL) at 4 percent LFL vapor concentration] [, benzene is less than 10 ppm PEL at 4 percent LFL vapor concentration] and oxygen content is a minimum of 19.5 percent.

h. An NFPA certified "Marine Chemist" [or "Gas Free Engineer"] has

certified that tank is safe for hot work, and that the required special precautionary measures have been taken due to the potential health hazard to the worker that still exists, even when the vapor concentration is well below the LFL. The Contractor shall be responsible for reviewing the record drawing(s) of the tank to be cleaned.

i. People entering the area leave all cigarettes and flame-producing devices at a previously determined location.

j. When work involves handling and disposal of hazardous waste, the Contractor has a copy of 40 CFR 260 to 266 in his possession.

3.1.2 Traffic Control: Direct traffic a minimum 200 feet away from the tank cleaning area. Set up road blocks and warning signs. Do not operate vehicles in hazardous areas.

3.1.3 Lavatory Facilities: Arrange for lavatory and toilet facilities [and, in the case of tanks for leaded fuel, provide showers for bathing]. (D,E)

3.1.4 Miscellaneous: Ensure that the manufacturers have labelled containers holding products involving hazards in use or storage, in accordance with 29 CFR 1910.1200. Label containers used to store, transport, or dispose of hazardous waste in accordance with 40 CFR 260 to 266 [and State Regulations]. Remove small objects of ferrous metal within the working areas to prevent the accidental striking of a spark. Place equipment upwind of tank openings at highest elevation possible; do not place in a spot lower than the surrounding terrain. Review drawings of the tank to be cleaned and brief workers on the location of pits, sumps, piping, and other tank appurtenances which could be hazardous to personnel. Provide floodlights to illuminate the work area without the need for battery operated handlights. Provide scaffolding, platforms, and ladders for secure, safe accessibility to tank surfaces. Install electrical equipment in accordance with API RP 500C. Provide floodlights to illuminate the work area without the need for battery operated handlights. Do not use artificial lights inside a tank until the tank is vapor-free. [Unless otherwise approved by the Contracting Officer, do not heat tanks during winter to provide personnel comfort or melt ice.]

3.1.4.1 Grounding and Bonding for Equipment: Provide grounding and bonding for equipment which may generate static electricity [, including air hose to sandblast nozzle]. Do not pass the air hose through an area where flammable vapors may exist.

3.1.4.2 Fire Extinguishers: Furnish [two] [____] carbon dioxide fire extinguishers of minimum 15 pound capacity each, in the immediate vicinity of the work. Provide a continuous fire watch. CAUTION: Do not discharge high pressure carbon dioxide extinguishers where explosive vapors exist since the discharge can cause a spark which will ignite the vapors. (H)

3.1.4.3 Disconnection of Pipelines: Disconnect pipelines connected to the tank. Insert a solid-plate blind flange between two flanges near the

tank, or remove a valve or piece of pipe and install a blind flange to prevent flammable material from entering the tank. [For underground tanks where connected pipelines are buried, blind off the pipelines at the nearest valve box.] Blind flanges shall be of sufficient strength to withstand pressure which might be exerted by the material being blanked off, and shall be gasketed on both sides if blind flange is inserted between two flanges. CAUTION: Do not disconnect piping or valves until it is certain the line has been emptied of fuel.

3.1.4.4 Removal of Ignition Sources: Remove sources of ignition from the cleaning area. Do not permit ignition producing devices, including matches, lighters or cigarettes, within 100 feet upwind and 200 feet downwind of a tank, or inside the tank farm, or within the tank firewall, whichever is farther.

3.1.4.5 Survey of Hazardous Areas: Carefully survey the entire area around the tank to be cleaned to ensure that there are no vapors present in the pit, low places, or hazardous areas and that unauthorized personnel are cleared from the area. Ensure that there is no possibility of anyone smoking in the immediate vicinity. Hazardous areas are defined as follows:

a. Interior of tanks.

b. Areas within 100 feet from points having flammable vapor emissions which, for example, are from the exhaust manholes of tanks under repair, open vents or pressure vacuum vents (breather valves) of active tanks in the vicinity of tanks under repair or cleaning. CAUTION: Allowance shall be made for 4 or more mile-per-hour winds by increasing the size of the hazardous area to a minimum of 200 feet on the downwind side.

[c. For aboveground tanks, areas within a common impoundment dike up to the height of the dike walls and within 10 feet in all directions of the exterior surfaces of tank shell and roof].

3.1.4.6 Exit from a Tank During Emergencies: To permit quick, free exit from a tank during emergencies, keep the area around the tank openings and emergency routes clear of obstructions.

3.2 INSPECTION:

3.2.1 Inspection of Equipment:

3.2.1.1 Respirators: Respirator users shall inspect their respirators in strict accordance with the instructions provided by the manufacturer.

3.2.1.2 Air Hose From Breathing-Air Supply (if air line respirators are used): Ensure that:

a. There are no breaks in outside covering;
b. Condition of gaskets is good;

c. Connections are tight; and

d. There are no restrictions in the hose.

3.2.1.3 Safety Harness and Life Line: Ensure that:

a. There is no frayed or weak material; and

b. Condition of harness is good;

3.2.1.4 Breathing-Air Supply Source: Ensure:

a. Good working condition; and

b. Location in vapor-free area.

c. Compliance with 29 CFR 1910.134 for breathing air quality, frequency of air analysis, and presence of safety devices.

d. Backup air supply source.

3.2.1.5 Monitoring Equipment: Calibrate each day before use:

a. Gas meter

b. Oxygen meter

[c. $H_2S$ Indicator]

[d. Lead-in-Air Analyzer]

3.2.1.6 Other Equipment: Ensure:

a. Proper grounding and bonding;

b. Explosion-proof motors; and

c. Explosion-proof lighting.

3.2.2 Personnel Inspection:

3.2.2.1 Personnel for Proper Attire Commensurate with Hazards Involved: Check for:

a. Clean clothing in good condition (wear freshly laundered clothing at the beginning of the job and at the start of each workday thereafter).

b. Boots and gloves of approved type and in good condition.

3.2.2.2 Breathing-Air Supply: If air line respirators are used, ensure that air is supplied to the facepiece at a rate of 4 to 15 cfm. If

self-contained breathing apparatus are used, ensure sufficient number of full replacement cylinders are available to last the duration of the job.

3.2.2.3 Harness and Lifeline: Harness and lifeline shall be in good condition and properly attached.

3.2.2.4 Gum or Tobacco Chewing: Ensure that gum or tobacco chewing is prohibited.

3.2.2.5 Physical Defects or Injuries: Ensure that people have no physical defects or injuries which may prevent wearing respirators or which may cause rescue to be difficult. No beards, sideburns, or large mustaches shall be allowed on people who must wear respirators.

3.2.2.6 Alcoholic Beverages and Drugs: Ensure that people entering the tank are not under the influence of alcoholic beverages and drugs.

[3.2.2.7 Females with Child-Bearing-Capability: Females with child-bearing capacity shall not be allowed to work in contaminated areas or in leaded gasoline or chemically contaminated tanks since they may be seriously affected by organic lead compound or other chemical contaminants.] (E)

3.2.2.8 Hazardous Areas: Check hazardous areas as defined in paragraph entitled "Survey of Hazardous Areas."

3.3 TABLE OF TANK HISTORY: (D)

| Tank Number | Tank Location | Tank Capacity | Date Constructed | Type of Lining (If Applicable) | Type of Fuel | Remarks from the Last Inspection |
|---|---|---|---|---|---|---|

3.4 FUEL REMOVAL: All possible fuel will be pumped or otherwise removed from the tank by the Government. Consider remaining fuel contaminated or waste fuel; pump into 55 gallon drums or other suitable containers. [Turn the remaining fuel over to the Government for use] [Dispose of the remaining fuel as directed by the Contracting Officer in accordance with approved procedures meeting local, state, and federal regulations]. Drums or tanks used for containerizing waste fuel will be furnished by the [Contractor] [Government].

3.5 IDENTIFICATION OF TANKS WITH HAZARDOUS WASTE SLUDGES AND RESIDUES: The following [tank is][tanks are] known or suspected to contain hazardous wastes: (I)

| Tank No. | Product | Hazardous Waste, Status, Type, and Basis-known [or suspect] |
|---|---|---|
| [1] | [MOGAS] | [Sludge and sandblast residue; Ignitability and Lead] |

3.6 TANK CLEANING: For the interior of the tanks, the shell, bottom, columns, roof, roof beams, and interior accessory equipment such as pumps, piping, and ladders, shall be cleaned [to bare metal] [not to bare metal but only to the sound surface of the lining or coating], free of rust, dirt, scale, loose materials, fuel, oil, grease, sludge, and other deleterious materials. [Do not damage sound existing lining material. Remove unsound or loose lining or coating and clean the surfaces exposed thereby to bare metal or concrete as applicable. Immediately notify the Contracting Officer if the lining or coating is deteriorated or loose].

3.6.1 [Lead Hazard Personnel Safety: Due to the lead hazard (inorganic and organic (TEL)) associated with this tank, comply with API 2015, API 2015A, and the applicable rules and regulations of the State of [Hawaii] [_____] and Federal Occupational Safety and Health Standards. If there is conflict among the API Publications, State, and Federal regulations; the most stringent criteria shall apply. Ensure that the requirements for protective clothing and equipment, monitoring to determine exposure levels, and all other relevant controls are complied with.] (E)

3.6.2 [Precautions for Airborne Lead: Since the tank is a known lead hazard, the Contractor shall, in accordance with API 2015A, ensure that the workers inside the tank wear the appropriate protective clothing and respiratory equipment as prescribed by API 2015 for the duration of the tank cleaning. Use only the types of respirators specified for "Respiratory Protection" under paragraph titled "Equipment." After completion of the cleaning operation, the Contractor has the option of allowing people to enter the tank without respiratory protective equipment, only after a lead-in-air analysis has been obtained in accordance with API 2015A.] (E) (J)

3.6.3 Water, Sediment, and Sludge Analysis: The water, sediment, and sludge remaining in the tank contain the following quantities of leachable metals as analyzed by the Government in accordance with 40 CFR 261. (K)

a. Water: _____

b. Sediment: _____

c. Sludge: _____

The Government analysis indicates that the water, sediment, and sludge are [nonhazardous] [hazardous]. The Contractor shall be responsible for independently testing the water, sediment, and sludge in accordance with 40 CFR 261 to verify the above. If the results differ such that the Contractor must handle the waste differently from the method specified, notify the contracting officer, and the Contractor will be subject to an equitable adjustment to the Contract under the Changes clause of the Contract Clauses. If the Contractor's test determines that the water, sediment, and sludge are hazardous, then the hazardous wastes shall be packaged, labeled, stored, transported, treated and disposed of in accordance with 40 CFR 260 through 266. Transporters, storers, treaters and disposers must be certified and have.

EPA ID numbers. Payment for disposal of hazardous waste will not be made until a complete hazardous waste manifest from the treatment or disposal facility is returned, and a copy furnished to the Government. [Deliver hazardous waste to the Government for disposal [as directed by the Contracting Officer.] [_____.]] (L)
Nonhazardous or hazardous wastes shall be handled and disposed of as described below.

3.6.4 Water Removal and Disposal: The Contractor shall pump or otherwise remove all water from the tank. The Contractor shall ensure that the sludge and sediment are not pumped out or mixed with the water. There are [___] gallons of [nonhazardous] [hazardous] water and that the water [can be disposed of into the berm area.] [shall be packaged, labeled, stored, transported, treated, and disposed of in accordance with 40 CFR 260 through 266.] [Deliver hazardous waste to the Government for disposal [as directed by the Contracting Officer.] [_____.]] (M) (L)

3.6.5 Sludge and Sediment Removal and Disposal: Squeegee or brush any sludge, sediment, or other loose material into piles, shovel into buckets or other suitable containers, and remove from the tank.

3.6.5.1 There are [___] barrels of [nonhazardous sediment and sludge in the tank that can be disposed of in [the berm area] [sanitary landfill.]] [Spread nonhazardous sludge as uniformly as possible over the area in a maximum 3-inch thick layer for weathering in the berm area. Fence the area temporarily and mark with a wood or metal sign. When the ambient temperatures are above 32 degrees F (zero degrees C), the weathering period shall be a minimum of 4 weeks. For colder temperatures, the weathering period shall be extended by the number of days the temperature falls below 32 degrees F (zero degrees C). After the required time elapses, remove the signs and fences.] (M) (N)

** OR **

3.6.5.1 There are [_____] barrels of nonhazardous sediment and sludge in the tank that shall be delivered to the Government for disposal in the Government operated oily waste reclamation plant. (M)

** OR **

3.6.5.1 There are [_____] barrels of hazardous sediment and sludge in the tank that shall be disposed of by the Contractor. Package, label, store, transport, treat, and dispose of hazardous sludge and sediment in accordance with 40 CFR 260 through 266. (M)

** OR **

3.6.5.1 There are [_____] barrels of hazardous sediment and sludge in the tank that shall be delivered to the Government for disposal. Package, label, accumulate, transport, treat, and dispose of hazardous sludge and sediment in accordance with 40 CFR 260 through 266. (L,M)

3.6.6 Washing: After water, fuel, and sludge have been removed, thoroughly wash the tank interior. Minimize the use of water; substitute brush blasting when practical. Start washing at the top of the walls and columns and work down to the floor. Wash the floor last starting from the sides and working towards the sump. Wash to remove oil, sludge, wax, tar, and other fuel residue adhering to the surface. Wash by any one or a combination of the following methods: (O)

a. Use only fresh water under pressure.

** OR **

a. Apply a detergent conforming to Fed. Spec. O-D-1276 by spray or brush and soak approximately 30 minutes.

** OR **

a. Apply a detergent cleaning solution by spray or brush and allow to soak approximately 30 minutes. The cleaning solution shall be either a one-to-one ratio of detergent conforming to Fed. Spec. O-D-1276 and solvent conforming to Fed. Spec. TT-T-291 or an equivalent commercial cleaning agent as approved by the Contracting Officer.

b. Hand-scrub the surfaces vigorously with long-handled stiff-bristle brushes. Wet the brushes intermittently with fresh [cleaning agent] during scrubbing process. For heavily oil-soaked areas which still appear to retain some residue after first scrubbing, [give a second application of cleaning agent and repeat the scrub process a second time.] [scrub until clean.]

c. Rinse the surfaces thoroughly with fresh water.

d. Brush-off blast clean.

3.6.7 Wash Water, [Detergent Solution,] and Sediment Removal: During the washing process, operate a portable pump continuously with suction hose extended to the tank bottom to remove water, [detergent,] dirt, oil, or other loose materials washed off. Following the final rinse, pump, squeege, and mop the tank dry.

a. The Contractor shall retest the water, sediment, and sludge in accordance with paragraph titled "Water, Sediment, and Sludge Analysis", if previous test results showed that the water, sediment, and sludge were hazardous.

b. The wash water is [nonhazardous and can be disposed of in the berm area.] [hazardous and shall be handled in accordance with paragraph titled "Water, Sediment, and Sludge Analysis."] (P)

** OR **

b. The water and detergent solution is nonhazardous and can be disposed of into the Navy Sewer System. The Contractor shall ensure that the wash water does not exceed the discharge limitations listed below. Notify the Contracting Officer and the Navy Sewage Treatment Plant Operator at least 24 hours prior to discharge into the Navy Sewer System. (Q)

TABLE 2. WASTE WATER DISCHARGE LIMITS TO SEWERS

| Item | Limits |
|---|---|
| (1) pH | 5.5-9.5 |
| (2) Oil and Grease (Hydrocarbon) | 50 mg/l Max. |
| (3) Surfactant (MBAS) | 30 mg/l Max. |
| (4) Lead | 0.6 mg/l Max. |
| (5) Total Identifiable Chlorinated Hydrocarbons | 0.04 mg/l Max. |
| (6) Benzene and Derivatives | 2.0 mg/l Max. |
| (7) Organic Solvents | 2.5 mg/l Max. |

If the discharge limits are exceeded for any of the above items, dispose of the water and detergent solution as directed by the Contracting Officer, at either the Navy's Industrial Waste Treatment Plant or the Oil Reclamation Plant.

c. For bidding purposes, assume that the sediment is [nonhazardous and can be disposed of [in the berm area] [in a sanitary landfill]] [hazardous and must be handled in accordance with paragraph entitled "Sludge and Sediment Removal and Disposal."].

3.6.8 Removal of Scale and Other Tenaciously Adhering Materials: Perform [sandblast cleaning] [or] [power wire brushing]. [The brush shall be made of spark resistant bronze wire.] After [sandblasting] [or] [power wire brushing], clean the entire tank interior surfaces by brushing, blowing with dry compressed air, and vacuuming. Remove all loose materials from the tank interior.

3.6.9 Disposal of Used Blasting Abrasive: Test used abrasive in accordance with 40 CFR 261 to determine if it is a hazardous waste using the EP toxicity test for metals. Handle and dispose of abrasive determined to be hazardous waste in acordance with 40 CFR 260 through 266. Dispose of abrasive which is not hazardous waste at a landfill off Government property in accordance with applicable regulations. The contract price will be adjusted if the used abrasive is determined to be hazardous waste. [However, payment for disposal treatment or disposal facilty is returned, and a copy furnished

to the Government.] [Deliver hazardous waste to the Government for disposal [as directed by the Contracting Officer].] (L)

3.6.10 Special Instructions for Cleaning Tank Storage JP-5 Fuel:

a. Comply with the precautions and procedures outlined above for cleaning petroleum storage tanks.

b. Use respiratory equipment specified for "Respiratory Protection" under paragraph titled "Equipment", in this section, at all times, regardless to whether or not the combustible gas indicator indicates any vapors present in the tank. (R)
Wear the respiratory protective equipment continuously until the tank side and bottom has been throughly cleaned, washed and dried.

c. [Throughly clean of fuel, rust and debris in the interior of each pontoon of the floating tanks.] (S)

3.6.11 Special Precautions for Tanks with Pipe Columns and Braces, Pontoons, and Leaking Bottoms: (T)

a. Pipes used for columns and braces, pontoons and leaking bottoms are a potential source of explosive vapors even after the tank is cleaned. The tank may be determined to be vapor free below 4 percent of lower explosive limit; but after one or two hours, explosive readings must again be obtained from these sources. The Contractor shall take readings at least every half hour when working in tanks after they have been cleaned and each floating roof or pan pontoon shall be checked individually with a combustible gas indicator.

b. If the repair work is to be performed on floating roof tanks, the interior of each pontoon on the roof shall be thoroughly cleaned of fuel, rust, water, and debris.

3.6.12 [Lead-Hazard-Free Tests: In accordance with API PUB 2015A, take lead-in-air tests to ensure that the tank is lead-hazard-free (CAUTION: Never take lead-hazard-free tests before or during cleaning, only after).] (E)

3.7 FINAL CLEANUP: After the Contracting Officer has inspected and accepted the tank cleaning and before final inspection, accomplish the following work:

3.7.1 Stenciling Tank: Stencil on the tank in 3/4-inch letters adjacent to the manhole openings the following data:

Date Cleaned - _____

Contractor Name - _____

Address - _____

3.7.2 Restoration of Site to Original Condition: [Do not reconnect

pipelines until application of interior and exterior coatings specified in other sections of this specification, have been completed.] Replace valves, piping, manhole covers, and similar items which were removed at the start of the job with new gasket material resistant to fuel. Pressure check valves and piping. Remove, from the site, debris and equipment and materials used for the cleaning operations. Restore the site to its original condition.

*** END OF SECTION *** (U)

GENERAL NOTES

1. Do not refer to this guide specification in the project specification. Use it as a manuscript to prepare the project specifications. Edit and modify this guide specification to meet project requirements. Where "as shown," "as indicated," "as detailed," or words of similar import are used, include all requirements so designated on the project drawings.

2. Do not include the following parts of this NFGS in the project specification:

    a. Table of Contents.
    b. Sketches.
    c. General Notes.
    d. Technical Notes.
    e. Other supplemental information, if any, attached to this guide specification.

    As the first step in editing this guide specification for inclusion in a project specification, detach all parts listed above and, where applicable, use them in the editing process. If required in the construction contract, sketches and figures shall be placed on the project drawings. Where there are no project drawings, sketches and figures may be included as a part of the project specification, if required.

3. Each capital letter in the right-hand margin of the text indicates that there is a technical note pertaining to that portion of the guide specification. Do not include these letters in the project specification. If this is a regionally tailored version of this NFGS, i.e., an EFD Regional Criteria Master, some technical notes and their designating letters may have been deleted.

4. Where numbers, symbols, words, phrases, clauses, sentences, or paragraphs in this guide specification are enclosed in brackets, [], a choice or modification must be made; delete inapplicable portion(s). Where blank spaces enclosed in brackets occur, insert appropriate data. Delete inapplicable paragraphs and renumber subsequent paragraphs accordingly.

5. Project specification number, section number, and page numbers shall be centered at the bottom of each page of the section created from this guide specification.

    EXAMPLE:

    05-84-1984
    13219-1

6. CAUTION: Coordination of this section with other sections of the project specification and with the drawings is mandatory. If materials or equipment are to be furnished under this section and installed under other sections or are indicated on the drawings, state that fact clearly for each type of material and item of equipment. Review the entire project

specification and drawings to ensure that language is included to provide complete and operational systems and equipment.

7. Specifications shall not repeat information shown on the drawings. Specifications shall establish the quality of materials and workmanship, methods of installation, equipment functions, and testing required for the project. Drawings shall indicate dimensions of construction, relationship of materials, quantities, and location and capacity of equipment.

8. The following information shall be shown on the project drawings:

   a. Site plan of project area showing surrounding area with tanks and other construction which affect safety distances from the tank to be cleaned.

   b. Plan and elevation of tank to be cleaned with associated piping and appurtenances.

9. Suggestions for improvement of this specification will be welcomed. Complete the attached DD Form 1426 and mail the original to:

COMMANDER
Pacific Division, Code 406C
Naval Facilities Engineering Command
Pearl Harbor, HI 96890-7300

Mail a copy to:

COMMANDER
Naval Facilities Engineering Command
Code DS02
200 Stovall Street
Alexandria, VA 22332-2300

## TECHNICAL NOTES

A. This guide specification covers the requirements for clean-up of the interior of concrete or steel tanks used for petroleum storage.

B. Paragraph 1.1: The latest issue of applicable publications shall be used, but only after reviewing the latest issue to ensure that it will satisfy the minimum essential requirements of the project. If the latest issue of a referenced publication does not satisfy project requirements:

   1. Use the issue shown; or
   2. Select and refer to a document which does; or
   3. Incorporate the pertinent requirements from the document into the project specification.

Use DD Form 1426 to inform the Preparing Activity and NAVFACENGCOM if the latest issue of a referenced publication is not compatible with this guide specification.

Delete those publications not referred to in the text of the section created from this guide specification.

C. Paragraph 1.2: Editing should include the following considerations:

1. In projects using the Contractor Quality Control System, add the words, "Submit to the Contracting Officer.", at submittals deemed sufficiently critical or complex or aesthetically significant to merit approval by the Government.

2. Do not include the vertical bars in the final manuscript of the project specification. (Project Submittals Lists may be extracted from project specifications prepared on NAVFAC-programmed word processors. Vertical bars indicate points at which automatically extracted entries will terminate.)

D. Paragraphs 1.2.4, 3.1.3, and 3.3: Data for these paragraphs should be obtained from the Commanding Officer of the individual Naval facility having tanks for cleaning.

E. Paragraphs 1.2.5.f, 1.3, 3.1.3, 3.2.2.7, 3.6.1, 3.6.2, and 3.6.12: Delete reference to API 2015A, brackets, and words within brackets if there is no leaded fuel in any tank. Delete reference to API 2015B if there is no open-top or covered floating roof tank.

F. Paragraph 1.2.6.1: Delete if hazardous waste is to be disposed of by the Government. Designer must verify that Government disposal is practical and make all arrangements for Government disposal.

G. Paragraph 2.1.1: Coordinate listing of cleaning agents with paragraph 3.6.6 on cleaning method.

H. Paragraph 3.1.4.2: Coordinate with the local fire department to determine the minimum quantities of fire extinguishers for each specific job.

I. Paragraph 3.5: Information on the hazardous waste characteristics of the sludge in the tanks should be provided by the activity. If not, sampling and analysis must be conducted during the 0-35 percent design stage to define properly scope and costs.

J. Paragraph 3.6.2: The following paragraphs can be inserted into the appropriate section (demolition, tank coating, or repair/modifications) for follow on work to the tank:

Since this tank is known to have contained leaded fuel, hot cutting and other dust producing operations may result in excessive levels of lead-in-air concentrations even after the tank has been cleaned. The

Contractor shall comply with API 2015, API 2015A, and the applicablerules and regulations of the State of [Hawaii] [_____] and Federal Occupational Safety and Health Standards. If there is any conflict among the API Publications, State, and Federal regulations, the more stringent criteria shall apply. The Contractor shall ensure that the requirements for protective clothing and equipment, monitoring to determine exposure levels, and all other relevant controls are complied with.

Assume that the air in the vicinity of any hot cutting or dust producing operation inside the tank will exceed the OSHA's permissible exposure limit (PEL, synonymous with threshold limit value, TLV) of 0.050 $mg/M^3$ for inorganic lead and 0.075 $mg/M^3$ for tetraethyl lead (TEL). Therefore, respiratory protective equipment specified for "Respiratory Protection" under paragraph titled "Equipment" and the appropriate protective clothing and controls will be required inside the tank.

K. Paragraph 3.6.3: All wastes shall be tested prior to tank cleaning, by the Government and by the Contractor, regardless of the tank's past history as to the storage of leaded fuel.

Use this paragraph if the Government has already tested the water, sediment, and sludge. If at all possible, the Government shall perform the necessary tests to determine if the wastes are hazardous or nonhazardous prior to bid. The Government test results should be presented in the Specification and used as a basis for bidding. This does not preclude independent testing required of the Contractor to verify the Government analysis. For Air Force projects, check latest Air Force requirements for handling of hazardous waste materials.

40 CFR Part 261 is the EPA criteria for hazardous waste. The concern with leaded fuel or any other lead product is the characteristic of toxicity. If the sample contains 5 mg/liter or more of lead, then the sample is considered a hazardous waste. The test method to determine the lead concentration is specifically defined in 40 CFR Part 261 and does not distinguish between inorganic and organic (TEL) lead. The dangers associated with organic lead (TEL) is related to personnel safety (its absorption into the human body through the skin or respiratory system) and is of no concern to EPA with regards to the handling and disposal of hazardous wastes. The EPA test measures the concentration of total lead which leaches out into solution. Lead in its pure or stable forms, such as lead weights, etc., that does not leach out into the test solution, is not a hazardous waste.

The EPA has proposed a new test procedure called Toxicity Characteristic Leaching Procedure (TCLP), which may be adopted in the near future. Changes may be required to specifications and cost estimates because of expanded testing requirements.

L. Paragraphs 3.6.3, 3.6.4, 3.6.5.1, and 3.6.9: When Government disposal of hazardous waste has been determined to be the most practical method of disposal, include the option for delivery of waste to the Government. Add details if necessary.

M. Paragraphs 3.6.4 and 3.6.5.1: The Government should estimate and indicate the quantity of water, sludge, sediment, and fuel, if any, remaining in the tank so that the Contractor can be more responsive in his bidding. Verify availability of Government disposal facilities.

N. Paragraph 3.6.5.1: Disposal of sludge and sediment in the berm area may interfere with the Contractor's operations if storage or lay down of materials within the berm is planned. State permit may be required for disposal in the berm area and should be obtained by the Government prior to advertising for bids.

O. Paragraph 3.6.6: This paragraph is applicable to concrete or steel tanks. Only water shall be used as the first preference. Steel tanks which have contained light products can normally be cleaned by washing down with fresh water under pressure. Detergent shall be considered, if water by itself will be inadequate to remove all fuel residue. Use detergent, if the tank service will be changed from leaded fuel to unleaded fuel. The detergent and solvent solution should be specified only, if the tank is expected to be heavily coated with fuel residue. The choice of cleaning agent shall be based on the type of fuel stored in the tank and the conditions expected. Consider brush blasting to minimize the use of water.

P. Paragraph 3.6.7.b: Use the first paragraph, if only fresh water is used for washing.

Q. Paragraph 3.6.7.b: Use the second paragraph, if detergent and/or solvent is used for washing. Verify existence of treatment and reclamation plants; if not available, revise wording and listed limits to suit project conditions. Check, if activity will allow dumping waste water into the sewer system.

R. Paragraph 3.6.10.b: JP-5 has a relatively low Reid vapor pressure, the combustible gas indicator will not ordinarily indicate any vapors present in the tank, at any time during the entire tank cleaning work. But this does not mean that hazardous flammable fuel vapors are not present.

S. Paragraph 3.6.10.c: Delete the paragraph, if there is no floating-roof tank.

T. Paragraph 3.6.11: Delete, if not applicable.

U. Following the text, not less than two nor more than six lines below the last line of text, insert *** END OF SECTION *** centered on the page.

*** E N D ***

# APPENDIX C

# CHARACTERISTICS OF COATINGS INCLUDING MATERIAL SAFETY DATA SHEETS

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Form Approved
OMB No. 44-R1387

# MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

## SECTION I

| | |
|---|---|
| MANUFACTURER'S NAME: Rowe Paint Manufacturing Company | EMERGENCY TELEPHONE NO.: (904) 358-8866 |
| ADDRESS (Number, Street, City, State, and ZIP Code): 144 Watts Street, Jacksonville, FL 32204 | |
| CHEMICAL NAME AND SYNONYMS | TRADE NAME AND SYNONYMS: PRIMER PRETREATMENT |
| CHEMICAL FAMILY: VINYL WASH COAT PRIMER | FORMULA: Mil-P-15328C, F-117 GREEN |

## SECTION II - HAZARDOUS INGREDIENTS

| PAINTS, PRESERVATIVES, & SOLVENTS | % | TLV (Units) | ALLOYS AND METALLIC COATINGS | % | TLV (Units) |
|---|---|---|---|---|---|
| PIGMENTS LAMPBLACK, ZINC YELLOW | 5.5 | | BASE METAL | | |
| CATALYST NONE | | | ALLOYS | | |
| VEHICLE NON HAZARDOUS | | | METALLIC COATINGS | | |
| SOLVENTS | 71 | 1100 | FILLER METAL PLUS COATING OR CORE FLUX | | |
| ADDITIVES PHOSPHORIC ACID | 3.5 | | OTHERS | | |
| OTHERS NONE | | | | | |

| HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES | % | TLV (Units) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

## SECTION III - PHYSICAL DATA

| | | | | | |
|---|---|---|---|---|---|
| BOILING POINT (°F.) | OVER | 173 | SPECIFIC GRAVITY ($H_2O$=1) | | 0.96 |
| VAPOR PRESSURE (mm Hg.) | OVER | 4.7 | PERCENT, VOLATILE BY VOLUME (%) | | 38 |
| VAPOR DENSITY (AIR=1) | OVER | 1.6 | EVAPORATION RATE (BUTYL ACETATE=1) | OVER | 0.4 |
| SOLUBILITY IN WATER | NEGLIGIBLE | | | | |
| APPEARANCE AND ODOR | PIGMENTED PAINT, ALCOHOL ODOR | | | | |

## SECTION IV - FIRE AND EXPLOSION HAZARD DATA

| | | | |
|---|---|---|---|
| FLASH POINT (Method used): 68 (TOC) | FLAMMABLE LIMITS | Lel: 1.3 | Uel: 19.0 |
| EXTINGUISHING MEDIA: $CO_2$, DRY CHEMICAL, FOAM, WATER FOG | | | |
| SPECIAL FIRE FIGHTING PROCEDURES: CONTAINERS EXPOSED TO FIRE SHOULD BE KEPT COOL WITH A WATER SPRAY. FIRE FIGHTERS SHOULD WEAR GOGGLES AND SELF CONTAINED BREATHING MASKS. | | | |
| UNUSUAL FIRE AND EXPLOSION HAZARDS: NONE | | | |



(Continued on reverse side)

## SECTION V - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE
1100 ppm

EFFECTS OF OVEREXPOSURE
BURNING OF EYES, SKIN IRRITATION, DIZZINESS, DOUBLE VISION, VOMITING, HEADACHES

EMERGENCY AND FIRST AID PROCEDURES
SKIN CONTACT: WASH WITH SOAP & WATER. REMOVE CONTAMINATED CLOTHING & LAUNDER BEFORE REUSE. EYE CONTACT: FLUSH WITH WATER FOR 15 MINUTES. INHALATION: REMOVE PERSON TO FRESH AIR. IF NEEDED, APPLY ARTIFICIAL RESPIRATION. GET MEDICAL ATTENTION OR ADVICE.

## SECTION VI - REACTIVITY DATA

| STABILITY | | | |
|---|---|---|---|
| | UNSTABLE | | CONDITIONS TO AVOID |
| | STABLE | XX | |

INCOMPATABILITY (Materials to Avoid)
MAY SOFTEN, SWELL, OR DETERIORATE RUBBER

HAZARDOUS DECOMPOSITION PRODUCTS
CARBON MONOXIDE, CARBON DIOXIDE, HYDROCARBONS, ZINC OXIDES, CHROMIC OXIDE.

| HAZARDOUS POLYMERIZATION | | |
|---|---|---|
| | MAY OCCUR | CONDITIONS TO AVOID |
| | WILL NOT OCCUR | XX |

## SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
AVOID OR SHUT OFF ALL IGNITION SOURCES. AVOID CONTACT WITH LIQUID. VENTILATE AREA. USE SELF CONTAINED AIR MASK FOR ENTRY. REMOVE SPILLS BY WIPING & CLEANING WITH A SUITABLE SOLVENT, TAKING PRECAUTIONS NORMAL TO ITS USE.

WASTE DISPOSAL METHOD
COLLECT CONTAINERS, STACK, AND PLACE FOR REFUSE DISPOSAL IN ACCORDANCE WITH POLLUTION REGULATIONS.

## SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)
AIR MASK WITH FULL FACE COVERAGE

| VENTILATION | | |
|---|---|---|
| | LOCAL EXHAUST | SPECIAL |
| | WHEN SPRAYING OR USING IN CONFINED AREA | |
| | MECHANICAL (General) | OTHER |
| | FOR BRUSH APPLICATION | |

| PROTECTIVE GLOVES | EYE PROTECTION |
|---|---|
| YES | WORKERS-GOGGLES, SPRAYERS-FULL FACE COVERAGE |

OTHER PROTECTIVE EQUIPMENT
STANDARD SHIPYARD CLOTHING, COVERING ALL EXPOSED SKIN.

## SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING
KEEP AWAY FROM HEAT SPARKS, AND OPEN FLAME. AVOID PROLONGED CONTACT WITH SKIN AND BREATHING OF VAPOR OR SPRAY MIST. WHEN APPLYING IN CLOSED AREAS, USE AIR SUPPLIED HOOD RESPIRATORS TO AVOID BREATHING CONCENTRATED VAPORS. CLOSE CONTAINER AFTER EACH USE. USE WITH ADEQUATE VENTILATION. KEEP OUT OF THE REACH OF CHILDREN.

ROWE PAINT MFG. CO.

# MATERIAL SAFETY DATA SHEET

(APPROVED BY U S DEPARTMENT OF LABOR - "ESSENTIALLY SIMILAR" TO FORM OSHA-20

The information contained in this data sheet is the best and most current information available at ROWE PAINT MFG. CO. . This technical data is an aid to supplement good painting practices and common sense in the use of this product.

| | |
|---|---|
| TRADE NAME OF MATERIAL | Polyurethane Primer — Component A |
| MANUFACTURER'S PRODUCT NO. | N-2636 |
| TYPE OF MATERIAL | CHEMICAL NAME AND SYNONYMS |
| | CHEMICAL FAMILY Polyester |

## PAINTS, PRESERVATIVES & SOLVENTS

| PIGMENTS | % | TLV (Units) | SOLVENTS | % | TLV (Units) |
|---|---|---|---|---|---|
| Zinc Chromate (Chromium VI) | [illegible] | [illegible] | Glycol Ether EE | [illegible] | 5ppm |
| | | | Ethyl Acetate | [illegible] | 400ppm |
| | | | N-Butyl Acetate | [illegible] | 150ppm |
| | | | Aromatic Hydrocarbon | [illegible] | 100ppm |
| CATALYST | | | ADDITIVES | | |
| None | | | Non-Hazardous | | |
| VEHICLE | | | OTHERS | | |
| Non-Hazardous | | | None | | |

| | | | |
|---|---|---|---|
| BOILING POINT °F) | 168°-246°F | SPECIFIC GRAVITY (H2O-1) | 1.47 |
| VAPOR PRESSURE (mm Hg.) 76.00 mmhc 20°C | | PERCENT VOLATILE BY VOLUME (%) | 48.7% |
| VAPOR DENSITY (AIR-1) | over 1 | EVAPORATION RATE (N-BUAC-1) | over 1 |
| SOLUBILITY IN WATER | Negligible | | |
| APPEARANCE AND ODOR | Yellow pigmented Paint; Acetate odor | | |

## SECTION IV-FIRE AND EXPLOSION INFORMATION

FLASH POINT 26.6 DEG F ( -3.0 DEG C)

EXPLOSIVE LIMIT (PRODUCT) LOWER - 2.2%

EXTINGUISHING MEDIA: ALCOHOL FOAM OR CARBON DIOXIDE OR DRY CHEMICAL

HAZARDOUS DECOMPOSITION PRODUCTS: MAY FORM TOXIC MATERIALS:, CARBON DIOXIDE AND CARBON MONOXIDE, VARIOUS HYDROCARBONS, ETC.

FIREFIGHTING PROCEDURES: WEAR SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE WHEN FIGHTING FIRES.

SPECIAL FIRE & EXPLOSION HAZARDS: VAPORS ARE HEAVIER THAN AIR AND MAY TRAVEL ALONG THE GROUND OR MAY BE MOVED BY VENTILATION AND IGNITED BY PILOT LIGHTS, OTHER FLAMES, SPARKS, HEATERS, SMOKING, ELECTRIC MOTORS, STATIC DISCHARGE, OR OTHER IGNITION SOURCES AT LOCATIONS DISTANT FROM MATERIAL HANDLING POINT.

NEVER USE WELDING OR CUTTING TORCH ON OR NEAR DRUM (EVEN EMPTY) BECAUSE PRODUCT (EVEN DUST RESIDUE) CAN IGNITE EXPLOSIVELY.

NFPA CODES: HEALTH- 1 FLAMMABILITY- 3 REACTIVITY- 0

THRESHOLD LIMIT VALUE 400 PPM

EFFECTS OF ACUTE OVEREXPOSURE, FOR PRODUCT

EYES - CAN CAUSE SEVERE IRRITATION, REDNESS, TEARING, BLURRED VISION
SKIN - PROLONGED OR REPEATED CONTACT CAN CAUSE MODERATE IRRITATION, DEFATTING, DERMATITIS.
BREATHING - EXCESSIVE INHALATION OF VAPORS CAN CAUSE NASAL AND RESPIRATORY IRRITATION, CENTRAL NERVOUS SYSTEM EFFECTS INCLUDING DIZZINESS, WEAKNESS, FATIGUE, NAUSEA, HEADACHE AND POSSIBLE UNCONSCIOUSNESS, AND EVEN ASPHYXIATION.
SWALLOWING - CAN CAUSE GASTROINTESTINAL IRRITATION, NAUSEA, VOMITING, AND DIARRHEA.

## SECTION V-HEALTH HAZARD DATA (CONTINUED)

FIRST AID,

IF ON SKIN, THOROUGHLY WASH EXPOSED AREA WITH SOAP AND WATER. REMOVE CONTAMINATED CLOTHING. LAUNDER CONTAMINATED CLOTHING BEFORE RE-USE.

IF IN EYES, FLUSH WITH LARGE AMOUNTS OF WATER, LIFTING UPPER AND LOWER LIDS OCCASIONALLY, GET MEDICAL ATTENTION.

IF SWALLOWED, IMMEDIATELY DRINK TWO GLASSES OF WATER AND INDUCE VOMITING BY EITHER GIVING IPECAC SYRUP OR BY PLACING FINGER AT BACK OF THROAT. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON. GET MEDICAL ATTENTION IMMEDIATELY.

IF BREATHED, IF AFFECTED, REMOVE INDIVIDUAL TO FRESH AIR. IF BREATHING IS DIFFICULT, ADMINISTER OXYGEN. IF BREATHING HAS STOPPED GIVE ARTIFICIAL RESPIRATION. KEEP PERSON WARM, QUIET AND GET MEDICAL ATTENTION.

EFFECTS OF CHRONIC OVEREXPOSURE, FOR PRODUCT

OVEREXPOSURE TO THIS MATERIAL (OR ITS COMPONENTS) HAS APPARENTLY BEEN FOUND TO CAUSE THE FOLLOWING EFFECTS IN LABORATORY ANIMALS:, ANEMIA, LIVER ABNORMALITIES, KIDNEY DAMAGE, LUNG DAMAGE

## SECTION VI-REACTIVITY DATA

HAZARDOUS POLYMERIZATION, CANNOT OCCUR

STABILITY, STABLE

INCOMPATIBILITY, AVOID CONTACT WITH:, STRONG OXIDIZING AGENTS., STRONG ALKALIES., STRONG MINERAL ACIDS.

## SECTION VII-SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED,

SMALL SPILL, ABSORB LIQUID ON PAPER, VERMICULITE, FLOOR ABSORBENT, OR OTHER ABSORBENT MATERIAL AND TRANSFER TO HOOD.

LARGE SPILL, ELIMINATE ALL IGNITION SOURCES (FLARES, FLAMES INCLUDING PILOT LIGHTS, ELECTRICAL SPARKS). PERSONS NOT WEARING PROTECTIVE EQUIPMENT SHOULD BE EXCLUDED FROM AREA OF SPILL UNTIL CLEAN-UP HAS BEEN COMPLETED. STOP SPILL AT SOURCE. DIKE AREA OF SPILL TO PREVENT SPREADING, PUMP LIQUID TO SALVAGE TANK. REMAINING LIQUID MAY BE TAKEN UP ON SAND, CLAY, EARTH, FLOOR ABSORBENT, OR OTHER ABSORBENT MATERIAL AND SHOVELED INTO CONTAINERS.

WASTE DISPOSAL METHOD,

SMALL SPILL, ALLOW VOLATILE PORTION TO EVAPORATE IN HOOD. ALLOW SUFFICIENT TIME FOR VAPORS TO COMPLETELY CLEAR HOOD DUCT WORK. DISPOSE OF REMAINING MATERIAL IN ACCORDANCE WITH APPLICABLE REGULATIONS.

LARGE SPILL, DESTROY BY LIQUID INCINERATION.
CONTAMINATED ABSORBENT MAY BE DEPOSITED IN A LANDFILL IN ACCORDANCE WITH LOCAL, STATE AND FEDERAL REGULATIONS.

## SECTION VIII-PROTECTIVE EQUIPMENT TO BE USED

RESPIRATORY PROTECTION, IF TLV OF THE PRODUCT OR ANY COMPONENT IS EXCEEDED, A NIOSH/MSHA JOINTLY APPROVED AIR SUPPLIED RESPIRATOR IS ADVISED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. OSHA REGULATIONS ALSO PERMIT OTHER NIOSH/MSHA RESPIRATORS UNDER SPECIFIED CONDITIONS. (SEE YOUR SAFETY EQUIPMENT SUPPLIER). ENGINEERING OR ADMINISTRATIVE CONTROLS SHOULD BE IMPLEMENTED TO REDUCE EXPOSURE.

VENTILATION, PROVIDE SUFFICIENT MECHANICAL (GENERAL AND/OR LOCAL EXHAUST) VENTILATION TO MAINTAIN EXPOSURE BELOW TLV(S).

PROTECTIVE GLOVES, WEAR RESISTANT GLOVES SUCH AS:, NEOPRENE, NITRILE RUBBER

EYE PROTECTION, CHEMICAL SPLASH GOGGLES IN COMPLIANCE WITH OSHA REGULATIONS ARE ADVISED, HOWEVER, OSHA REGULATIONS ALSO PERMIT OTHER TYPE SAFETY GLASSES. (CONSULT YOUR SAFETY EQUIPMENT SUPPLIER)

OTHER PROTECTIVE EQUIPMENT, TO PREVENT REPEATED OR PROLONGED SKIN CONTACT, WEAR IMPERVIOUS CLOTHING AND BOOTS.

CONTAINERS OF THIS MATERIAL MAY BE HAZARDOUS WHEN EMPTIED SINCE EMPTIED CONTAINERS RETAIN PRODUCT RESIDUES (VAPOR, LIQUID, AND/OR SOLID), ALL HAZARD PRECAUTIONS GIVEN IN THE DATA SHEET MUST BE OBSERVED.

THE INFORMATION ACCUMULATED HEREIN IS BELIEVED TO BE ACCURATE BUT IS NOT WARRANTED TO BE WHETHER ORIGINATING WITH THE COMPANY OR NOT. RECIPIENTS ARE ADVISED TO CONFIRM IN ADVANCE OF NEED THAT THE INFORMATION IS CURRENT, APPLICABLE, AND SUITABLE TO THEIR CIRCUMSTANCES.

## DEFINITIONS

THIS DEFINITION PAGE IS INTENDED FOR USE WITH MATERIAL SAFETY DATA SHEETS SUPPLIED BY ASHLAND OIL, INC. AND ITS DIVISIONS. RECIPIENTS OF THESE DATA SHEETS SHOULD CONSULT THE OSHA SAFETY AND HEALTH STANDARDS (29 CFR 1910), PARTICULARLY SUBPART G - OCCUPATIONAL HEALTH AND ENVIRONMENTAL CONTROL, AND SUBPART I - PERSONAL PROTECTIVE EQUIPMENT, FOR GENERAL GUIDANCE ON CONTROL OF POTENTIAL OCCUPATIONAL HEALTH AND SAFETY HAZARDS.

### SECTION I
### PRODUCT IDENTIFICATION

GENERAL OR GENERIC ID: CHEMICAL FAMILY OR PRODUCT DESCRIPTION.

DOT HAZARD CLASSIFICATION: PRODUCT MEETS DOT CRITERIA FOR HAZARDS LISTED.

### SECTION II
### COMPONENTS

COMPONENTS ARE LISTED IN THIS SECTION IF THEY PRESENT A PHYSICAL OR HEALTH HAZARD AND ARE PRESENT AT OR ABOVE 1% IN THE MIXTURE. IF A COMPONENT IS IDENTIFIED AS A CARCINOGEN BY NTP, IARC OR OSHA AS OF THE DATE ON THE MSDS, IT WILL BE LISTED AND FOOTNOTED IN THIS SECTION WHEN PRESENT AT OR ABOVE 0.1% IN THE PRODUCT. NEGATIVE CONCLUSIONS CONCERNING CARCINOGENICITY ARE NOT REPORTED. ADDITIONAL INFORMATION MAY BE FOUND IN SECTION V. OTHER COMPONENTS MAY BE LISTED IF DEEMED APPROPRIATE.

IDENTITIES OF COMPONENTS LISTED GENERALLY ARE DECLARED TRADE SECRET.

EXPOSURE RECOMMENDATIONS ARE FOR COMPONENTS. OSHA PERMISSIBLE EXPOSURE LIMITS (PELS) AND AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH) THRESHOLD LIMIT VALUES (TLVS) APPEAR ON THE LINE WITH THE COMPONENT IDENTIFICATION. OTHER RECOMMENDATIONS APPEAR AS FOOTNOTES.

### SECTION III
### PHYSICAL DATA

BOILING POINT: OF PRODUCT IF KNOWN. THE LOWEST VALUE OF THE COMPONENTS IS LISTED FOR MIXTURES.

VAPOR PRESSURE: OF PRODUCT IF KNOWN. THE HIGHEST VALUE OF THE COMPONENTS IS LISTED FOR MIXTURES.

VAPOR DENSITY: COMPARED TO AIR = 1. IF SPECIFIC VAPOR DENSITY OF PRODUCT IS NOT KNOWN, THE VALUE IS EXPRESSED AS LIGHTER OR HEAVIER THAN AIR.

SPECIFIC GRAVITY: COMPARED TO WATER = 1. IF SPECIFIC GRAVITY OF PRODUCT IS NOT KNOWN, THE VALUE IS EXPRESSED AS LESS THAN OR GREATER THAN WATER.

PH: IF APPLICABLE.

PERCENT VOLATILES: PERCENTAGE OF MATERIAL WITH INITIAL BOILING POINT BELOW 425 DEGREES FAHRENHEIT.

EVAPORATION RATE: INDICATED AS FASTER OR SLOWER THAN ETHYL ETHER, UNLESS OTHERWISE STATED.

### SECTION IV
### FIRE AND EXPLOSION INFORMATION

FLASH POINT: METHOD IDENTIFIED.

EXPLOSION LIMITS: FOR PRODUCT (IF KNOWN). THE LOWEST VALUE OF THE COMPONENTS IS LISTED FOR MIXTURES.

HAZARDOUS DECOMPOSITION PRODUCTS: KNOWN OR EXPECTED HAZARDOUS PRODUCTS RESULTING FROM HEATING, BURNING, OR OTHER REACTIONS.

### SECTION IV (CONT.)

EXTINGUISHING MEDIA: FOLLOWING NATIONAL FIRE PROTECTION ASSOCIATION CRITERIA.

FIREFIGHTING PROCEDURES: MINIMUM EQUIPMENT TO PROTECT FIREFIGHTERS FROM TOXIC PRODUCTS OF VAPORIZATION, COMBUSTION OR DECOMPOSITION IN FIRE SITUATIONS. OTHER FIREFIGHTING HAZARDS MAY ALSO BE INDICATED.

SPECIAL FIRE AND EXPLOSION HAZARDS: STATES HAZARDS NOT COVERED BY OTHER SECTIONS.

NFPA CODES: HAZARD RATINGS ASSIGNED BY THE NATIONAL FIRE PROTECTION ASSOCIATION.

### SECTION V
### HEALTH HAZARD DATA

PERMISSIBLE EXPOSURE LIMIT: FOR PRODUCT.

THRESHOLD LIMIT VALUE: FOR PRODUCT.

EFFECTS OF ACUTE OVEREXPOSURE: POTENTIAL LOCAL AND SYSTEMIC EFFECTS DUE TO SINGLE OR SHORT TERM OVEREXPOSURE TO THE EYES AND SKIN OR THROUGH INHALATION OR INGESTION.

EFFECTS OF CHRONIC OVEREXPOSURE: POTENTIAL LOCAL AND SYSTEMIC EFFECTS DUE TO REPEATED OR LONG TERM OVEREXPOSURE TO THE EYES AND SKIN OR THROUGH INHALATION OR INGESTION.

FIRST AID: PROCEDURES TO BE FOLLOWED WHEN DEALING WITH ACCIDENTAL OVEREXPOSURES.

PRIMARY ROUTE OF ENTRY: BASED ON PROPERTIES AND EXPECTED USE.

### SECTION VI
### REACTIVITY DATA

HAZARDOUS POLYMERIZATION: CONDITIONS TO AVOID TO PREVENT HAZARDOUS POLYMERIZATION RESULTING IN A LARGE RELEASE OF ENERGY.

STABILITY: CONDITIONS TO AVOID TO PREVENT HAZARDOUS OR VIOLENT DECOMPOSITION.

INCOMPATIBILITY: MATERIALS AND CONDITIONS TO AVOID TO PREVENT HAZARDOUS REACTIONS.

### SECTION VII
### SPILL OR LEAK PROCEDURES

REASONABLE PRECAUTIONS TO BE TAKEN AND METHODS OF CONTAINMENT, CLEAN-UP AND DISPOSAL. CONSULT FEDERAL, STATE AND LOCAL REGULATIONS FOR ACCEPTED PROCEDURES AND ANY REPORTING OR NOTIFICATION REQUIREMENTS.

### SECTION VIII
### PROTECTIVE EQUIPMENT TO BE USED

PROTECTIVE EQUIPMENT WHICH MAY BE NEEDED WHEN HANDLING THE PRODUCT.

### SECTION IX
### SPECIAL PRECAUTIONS OR OTHER COMMENTS

COVERS ANY RELEVANT POINTS NOT PREVIOUSLY MENTIONED.

## ADDITIONAL COMMENTS

CONTAINERS SHOULD BE EITHER RECONDITIONED BY CERTIFIED FIRMS OR PROPERLY DISPOSED OF BY APPROVED FIRMS. DISPOSAL OF CONTAINERS SHOULD BE IN ACCORDANCE WITH APPLICABLE LAWS AND REGULATIONS. "EMPTY" DRUMS SHOULD NOT BE GIVEN TO INDIVIDUALS. SERIOUS ACCIDENTS HAVE RESULTED FROM THE MISUSE OF "EMPTIED" CONTAINERS (DRUMS, PAILS, ETC.). REFER TO SECTIONS IV AND IX.

ROWE PAINT MFG. CO.

# MATERIAL SAFETY DATA SHEET

(APPROVED BY U.S. DEPARTMENT OF LABOR - "ESSENTIALLY SIMILAR" TO FORM OSHA-20

The information contained in this data sheet is the best and most current information available at Rowe Paint Mfg. Co. . This technical data is an aid to supplement good painting practices and common sense in the use of this product

| | |
|---|---|
| TRADE NAME OF MATERIAL | Polyurethane Primer Component B |
| MANUFACTURER'S PRODUCT NO | N-2636 CHEMICAL NAME AND SYNONYMS |
| TYPE OF MATERIAL | CHEMICAL FAMILY Aromatic Polyisocyanate |

## I. PRODUCT IDENTIFICATION

PRODUCT NAME.....: Mondur CB-75
PRODUCT CODE NUMBER.....: D-065
CHEMICAL FAMILY.....: Aromatic Polyisocyanate
CHEMICAL NAME.....: Toluene Diisocyanate based adduct
SYNONYMS.....: Toluene diisocyanate prepolymer
T.S.C.A. STATUS.....: OK
OSHA HAZARD COMMUNICATION STATUS.....: This product is hazardous under the criteria of the federal OSHA Hazard Communication Standard 29 CFR 1910.1200.
CHEMICAL FORMULA.....: Oligomeric resin, not applicable

## II. HAZARDOUS INGREDIENTS

| COMPONENTS: | %: | OSHA-PEL | ACGIH-TLV |
|---|---|---|---|
| Ethyl Acetate (EA) (CAS# 141-78-6) | 25% | 400 ppm TWA | 400 ppm TWA |
| Aromatic Polyisocyanate | 75% | Not Established | Not Established |
| Toluene Diisocyanate (TDI) (CAS# 26471-62-5) | * | 0.02 ppm Ceiling | 0.005 ppm TWA<br>0.02 ppm STEL |

TDI residual monomer content is less than 0.7% based on resin solids.

## III. PHYSICAL DATA

APPEARANCE.....: Liquid
COLOR.....: Clear yellow
ODOR.....: Of solvent
MELT POINT/FREEZE POINT..: Not Established
BOILING POINT.....: EA - 170°F (77°C)
VAPOR PRESSURE.....: EA - 86 mmHg @ 68°F (20°C)
VAPOR DENSITY (AIR=1)....: EA - 3.0
SPECIFIC GRAVITY.....: 1.19
BULK DENSITY.....: 9.9 lbs/gal
SOLUBILITY IN WATER.....: Isocyanate - Insoluble, reacts with water to liberate $CO_2$ gas; EA - 7.4%
% VOLATILE BY VOLUME.....: About 34%

## IV. FIRE & EXPLOSION DATA

FLASH POINT °F(°C).....: 30°F (-1°C) TAG Closed Cup (ASTM D56)
FLAMMABLE LIMITS - EA
Lel.....: 2.2
Uel.....: 11.0
EXTINGUISHING MEDIA.....: Dry chemical (e.g. monoammonium phosphate, potassium sulfate, and potassium chloride), carbon dioxide
SPECIAL FIRE FIGHTING PROCEDURES/UNUSUAL FIRE OR EXPLOSION HAZARDS:
Full emergency equipment with self-contained breathing apparatus and full protective clothing (such as rubber gloves, boots, bands around legs, arms and waist) should be worn by firefighters. No skin surface should be exposed. During a fire, TDI vapors and other irritating, highly toxic gases may be generated by thermal decomposition or combustion. (See Section VIII). Closed container may explode when exposed to extreme heat or burst when contaminated with water ($CO_2$ evolved). Solvent vapors may be heavier than air. Under conditions of stagnant air, vapors may build up and travel along the ground to an ignition source which may result in a flash back to the source of the vapors.

## V. HUMAN HEALTH DATA

PRIMARY ROUTE(S) OF EXPOSURE.....: Inhalation, Skin Contact, Eyes
HUMAN EFFECTS AND SYMPTOMS OF OVEREXPOSURE
INHALATION

Acute Exposure: TDI vapors or mist at concentrations above the TLV can irritate (burning sensation) the mucous membranes in the respiratory tract (nose, throat, lungs) causing runny nose, sore throat, coughing, chest discomfort, shortness of breath and reduced lung function (breathing obstruction). Persons with a preexisting, nonspecific bronchial hyperreactivity can respond to concentrations below the TLV with similar symptoms as well as asthma attack. Exposure well above the TLV may lead to bronchitis, bronchial spasm and pulmonary edema (fluid in lungs). These effects are usually reversible. Chemical or hypersensitive pneumonitis, with flu-like symptoms (e.g., fever, chills), has also been reported. These symptoms can be delayed up to several hours after exposure.

Solvent vapors are irritating to the eyes, nose, throat and respiratory tract resulting in red, itchy eyes, dryness of the throat and tightness in the chest. Other possible symptoms of overexposure include headache, nausea, narcosis, fatigue and loss of appetite. Ethyl Acetate odor may be objectionable at 200 ppm and is mildly irritating to the eyes, nose and throat at 400 ppm. At concentrations in excess of 13,000 ppm Ethyl Acetate is only mildly narcotic.

Chronic Exposure: As a result of previous repeated overexposures or a single large dose, certain individuals may develop isocyanate sensitization (chemical asthma) which will cause them to react to a later exposure to isocyanate at levels well below the TLV. These symptoms, which can include chest tightness, wheezing, cough, shortness of breath or asthmatic attack, could be immediate or delayed up to several hours

after exposure. Similar to many non-specific asthmatic responses, there are reports that once sensitized an individual can experience these symptoms upon exposure to dust, cold air or other irritants. This increased lung sensitivity can persist for weeks and in severe cases for several years. Chronic overexposure to isocyanate has also been reported to cause lung damage (including decrease in lung function) which may be permanent. Sensitization can either be temporary or permanent.

Chronic exposure to organic solvents has been associated with various neurotoxic effects including permanent brain and nervous system damage. Symptoms include loss of memory, loss of intellectual ability and loss of coordination.

SKIN CONTACT

Acute Exposure: Isocyanates react with skin protein and moisture and can cause irritation which may include the following symptoms: reddening, swelling, rash, scaling or blistering. Cured material is difficult to remove.

Repeated or prolonged skin contact with the solvent can result in dry, defatted and cracked skin causing increased susceptibility to infection. In addition, dermatitis and skin rash and redness may occur from skin contact. EA does not readily penetrate the skin to cause systemic toxic effects.

Chronic: Prolonged contact can cause reddening, swelling, rash, scaling, blistering, and, in some cases, skin sensitization. Individuals who have developed a skin sensitization can develop these symptoms as a result of contact with very small amounts of liquid material or as a result of exposure to vapor.

EYE CONTACT

Acute Exposure: Liquid, aerosols or vapors are severely irritating and can cause pain, tearing, reddening and swelling. If left untreated, corneal damage can occur and injury is slow to heal. However, damage is usually reversible. See Section VI for treatment.

Chronic Exposure: Prolonged vapor contact may cause conjunctivitis.

INGESTION

Acute Exposure: Can result in irritation in the mouth, stomach tissue and digestive tract. Symptoms can include sore throat, abdominal pain, nausea, vomiting and diarrhea. Vomiting may cause aspiration resulting in chemical pneumonitis.

Chronic Exposure: None known.

MEDICAL CONDITIONS

AGGRAVATED BY EXPOSURE..: Asthma, other respiratory disorders (bronchitis, emphysema, bronchial hyperreactivity), skin allergies, eczema.

CARCINOGENICITY

NTP.....: The National Toxicology Program reported that TDI caused an increase in the number of tumors in exposed rats over those counted in non-exposed rats. The TDI was administered in corn-oil and introduced into the stomach through a tube. Based on this study, the NTP has listed TDI as a substance that may reasonably be anticipated to be a carcinogen in its Fourth Annual Report on Carcinogens..

ROWE PAINT MFG. CO.

# MATERIAL SAFETY DATA SHEET

(APPROVED BY U S DEPARTMENT OF LABOR - "ESSENTIALLY SIMILAR" TO FORM OSHA-20

The information contained in this data sheet is the best and most current information available at ROWE PAINT MFG. CO. . Th.s technical data is an aid to supplement good painting practices and common sense in the use of this product.

| | |
|---|---|
| TRADE NAME OF MATERIAL | Polyurethane Intermediate Coat . Component A |
| MANUFACTURER'S PRODUCT NO | N-3633 |
| TYPE OF MATERIAL | CHEMICAL NAME AND SYNONYMS |
| CHEMICAL FAMILY | Polyester Resin/Hydroxy Terminated Linear Polyester Polyol |

## PAINTS, PRESERVATIVES & SOLVENTS

| PIGMENTS | % | TLV (Units) | SOLVENTS | % | TLV (Units) |
|---|---|---|---|---|---|
| Non-Hazardous | | | Ethyl Acetate | 6.9 | 400ppm |
| | | | N-Butyl Acetate | 6.9 | 150ppm |
| | | | Glycol Ether EE | 6.9 | 5ppm |
| | | | Aromatic Hydrocarbons | 6.9 | 100ppm |
| CATALYST | | | ADDITIVES | | |
| None | | | Non-Hazardous | | |
| VEHICLE | | | OTHERS | | |
| Non-Hazardous | | | None | | |

| | | | |
|---|---|---|---|
| BOILING POINT °F) | 168°-246°F | SPECIFIC GRAVITY (H2O-1) | 1.57 |
| VAPOR PRESSURE (mm Hg.) | 76.00 mmhg @ 2C°C | PERCENT VOLATILE BY VOLUME (%) | 48.8% |
| VAPOR DENSITY (AIR-1) | Over 1 | EVAPORATION RATE (N-BUAC-1) | Over 1 |
| SOLUBILITY IN WATER | Negligible | | |
| APPEARANCE AND ODOR | Green Pigmented Paint, Acetate Odor | | |

## SECTION IV-FIRE AND EXPLOSION INFORMATION

FLASH POINT 26.0 DEG F ( -3.3 DEG C)

EXPLOSIVE LIMIT (PRODUCT) LOWER - 2.2%

EXTINGUISHING MEDIA: ALCOHOL FOAM OR CARBON DIOXIDE OR DRY CHEMICAL

HAZARDOUS DECOMPOSITION PRODUCTS: MAY FORM TOXIC MATERIALS:, CARBON DIOXIDE AND CARBON MONOXIDE, VARIOUS HYDROCARBONS, ETC.

FIREFIGHTING PROCEDURES: WEAR SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE WHEN FIGHTING FIRES.

SPECIAL FIRE & EXPLOSION HAZARDS: VAPORS ARE HEAVIER THAN AIR AND MAY TRAVEL ALONG THE GROUND OR MAY BE MOVED BY VENTILATION AND IGNITED BY PILOT LIGHTS, OTHER FLAMES, SPARKS, HEATERS, SMOKING, ELECTRIC MOTORS, STATIC DISCHARGE, OR OTHER IGNITION SOURCES AT LOCATIONS DISTANT FROM MATERIAL HANDLING POINT.

NEVER USE WELDING OR CUTTING TORCH ON OR NEAR DRUM (EVEN EMPTY) BECAUSE PRODUCT (EVEN JUST RESIDUE) CAN IGNITE EXPLOSIVELY.

NFPA CODES: HEALTH- 1 FLAMMABILITY- 3 REACTIVITY -

## SECTION V-HEALTH HAZARD DATA

PERMISSIBLE EXPOSURE LEVEL 400 PPM

THRESHOLD LIMIT VALUE 400 PPM

### EFFECTS OF ACUTE OVEREXPOSURE, FOR PRODUCT

EYES - CAN CAUSE SEVERE IRRITATION, REDNESS, TEARING, BLURRED VISION.
SKIN - PROLONGED OR REPEATED CONTACT CAN CAUSE MODERATE IRRITATION, DEFATTING, DERMATITIS.
BREATHING - EXCESSIVE INHALATION OF VAPORS CAN CAUSE NASAL AND RESPIRATORY IRRITATION, CENTRAL NERVOUS SYSTEM EFFECTS INCLUDING DIZZINESS, WEAKNESS, FATIGUE, NAUSEA, HEADACHE AND POSSIBLE UNCONSCIOUSNESS, AND EVEN ASPHYXIATION.
SWALLOWING - CAN CAUSE GASTROINTESTINAL IRRITATION, NAUSEA, VOMITING, AND DIARRHEA.

## SECTION V-HEALTH HAZARD DATA (CONTINUED)

### FIRST AID,

IF ON SKIN, THOROUGHLY WASH EXPOSED ARE. WITH SOAP AND WATER. REMOVE CONTAMINATED CLOTHING. LAUNDER CONTAMINATED CLOTHING BEFORE RE-USE.

IF IN EYES, FLUSH WITH LARGE AMOUNTS OF WATER, LIFTING UPPER AND LOWER LIDS OCCASIONALLY, GET MEDICAL ATTENTION.

IF SWALLOWED, IMMEDIATELY DRINK TWO GLASSES OF WATER AND INDUCE VOMITING BY EITHER GIVING IPECAC SYRUP OR BY PLACING FINGER AT BACK OF THROAT. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON. GET MEDICAL ATTENTION IMMEDIATELY.

IF BREATHED, IF AFFECTED, REMOVE INDIVIDUAL TO FRESH AIR. IF BREATHING IS DIFFICULT ADMINISTER OXYGEN. IF BREATHING HAS STOPPED GIVE ARTIFICIAL RESPIRATION. KEEP PERSON WARM, QUIET AND GET MEDICAL ATTENTION.

### EFFECTS OF CHRONIC OVEREXPOSURE, FOR PRODUCT

OVEREXPOSURE TO THIS MATERIAL (OR ITS COMPONENTS) HAS APPARENTLY BEEN FOUND TO CAUSE THE FOLLOWING EFFECTS IN LABORATORY ANIMALS:, ANEMIA, LIVER ABNORMALITIES, KIDNEY DAMAGE, LUNG DAMAGE

## SECTION VI-REACTIVITY DATA

HAZARDOUS POLYMERIZATION, CANNOT OCCUR

STABILITY, STABLE

INCOMPATIBILITY, AVOID CONTACT WITH:, STRONG OXIDIZING AGENTS., STRONG ALKALIES., STRONG MINERAL ACIDS.

## SECTION VII-SPILL OR LEAK PROCEDURES

### STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED,

SMALL SPILL, ABSORB LIQUID ON PAPER, VERMICULITE, FLOOR ABSORBENT, OR OTHER ABSORBENT MATERIAL AND TRANSFER TO HOOD.

LARGE SPILL, ELIMINATE ALL IGNITION SOURCES (FLARES, FLAMES INCLUDING PILOT LIGHTS, ELECTRICAL SPARKS). PERSONS NOT WEARING PROTECTIVE EQUIPMENT SHOULD BE EXCLUDED FROM AREA OF SPILL UNTIL CLEAN-UP HAS BEEN COMPLETED. STOP SPILL AT SOURCE, DIKE AREA OF SPILL TO PREVENT SPREADING, PUMP LIQUID TO SALVAGE TANK. REMAINING LIQUID MAY BE TAKEN UP ON SAND, CLAY, EARTH, FLOOR ABSORBENT, OR OTHER ABSORBENT MATERIAL AND SHOVELED INTO CONTAINERS.

### WASTE DISPOSAL METHOD,

SMALL SPILL, ALLOW VOLATILE PORTION TO EVAPORATE IN HOOD. ALLOW SUFFICIENT TIME FOR VAPORS TO COMPLETELY CLEAR HOOD DUCT WORK. DISPOSE OF REMAINING MATERIAL IN ACCORDANCE WITH APPLICABLE REGULATIONS.

LARGE SPILL, DESTROY BY LIQUID INCINERATION.
CONTAMINATED ABSORBENT MAY BE DEPOSITED IN A LANDFILL IN ACCORDANCE WITH LOCAL, STATE AND FEDERAL REGULATIONS.

## SECTION VIII-PROTECTIVE EQUIPMENT TO BE USED

RESPIRATORY PROTECTION, IF TLV OF THE PRODUCT OR ANY COMPONENT IS EXCEEDED, A NIOSH/MSHA JOINTLY APPROVED AIR SUPPLIED RESPIRATOR IS ADVISED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. OSHA REGULATIONS ALSO PERMIT OTHER NIOSH/MSHA RESPIRATORS UNDER SPECIFIED CONDITIONS. (SEE YOUR SAFETY EQUIPMENT SUPPLIER). ENGINEERING OR ADMINISTRATIVE CONTROLS SHOULD BE IMPLEMENTED TO REDUCE EXPOSURE.

VENTILATION, PROVIDE SUFFICIENT MECHANICAL (GENERAL AND/OR LOCAL EXHAUST) VENTILATION TO MAINTAIN EXPOSURE BELOW TLV(S).

PROTECTIVE GLOVES, WEAR RESISTANT GLOVES SUCH AS:, NEOPRENE, NITRILE RUBBER

EYE PROTECTION, CHEMICAL SPLASH GOGGLES IN COMPLIANCE WITH OSHA REGULATIONS ARE ADVISED, HOWEVER, OSHA REGULATIONS ALSO PERMIT OTHER TYPE SAFETY GLASSES. (CONSULT YOUR SAFETY EQUIPMENT SUPPLIER)

OTHER PROTECTIVE EQUIPMENT, TO PREVENT REPEATED OR PROLONGED SKIN CONTACT, WEAR IMPERVIOUS CLOTHING AND BOOTS.

## SECTION IX - SPECIAL PRECAUTIONS OR OTHER COMMENTS

CONTAINERS OF THIS MATERIAL MAY BE HAZARDOUS WHEN EMPTIED. SINCE EMPTIED CONTAINERS RETAIN PRODUCT RESIDUES (VAPOR, LIQUID, AND/OR SOLID), ALL HAZARD PRECAUTIONS GIVEN IN THE DATA SHEET MUST BE OBSERVED.

THE INFORMATION ACCUMULATED HEREIN IS BELIEVED TO BE ACCURATE BUT IS NOT WARRANTED TO BE WHETHER ORIGINATING WITH THE COMPANY OR NOT. RECIPIENTS ARE ADVISED TO CONFIRM IN ADVANCE OF NEED THAT THE INFORMATION IS CURRENT, APPLICABLE, AND SUITABLE TO THEIR CIRCUMSTANCES.

### EXPLANATION

THIS DEFINITION PAGE IS INTENDED FOR USE WITH MATERIAL SAFETY DATA SHEETS SUPPLIED BY ASHLAND OIL, INC. AND ITS DIVISIONS. RECIPIENTS OF THESE DATA SHEETS SHOULD CONSULT THE OSHA SAFETY AND HEALTH STANDARDS (29 CFR 1910). PARTICULARLY SUBPART G - OCCUPATIONAL HEALTH AND ENVIRONMENTAL CONTROL, AND SUBPART I - PERSONAL PROTECTIVE EQUIPMENT, FOR GENERAL GUIDANCE ON CONTROL OF POTENTIAL OCCUPATIONAL HEALTH AND SAFETY HAZARDS.

### SECTION I
### PRODUCT IDENTIFICATION

GENERAL OR GENERIC ID: CHEMICAL FAMILY OR PRODUCT DESCRIPTION.

DOT HAZARD CLASSIFICATION: PRODUCT MEETS DOT CRITERIA FOR HAZARDS LISTED.

### SECTION II
### COMPONENTS

COMPONENTS ARE LISTED IN THIS SECTION IF THEY PRESENT A PHYSICAL OR HEALTH HAZARD AND ARE PRESENT AT OR ABOVE 1% IN THE MIXTURE. IF A COMPONENT IS IDENTIFIED AS A CARCINOGEN BY NTP, IARC OR OSHA AS OF THE DATE ON THE MSDS, IT WILL BE LISTED AND FOOTNOTED IN THIS SECTION WHEN PRESENT AT OR ABOVE 0.1% IN THE PRODUCT. NEGATIVE CONCLUSIONS CONCERNING CARCINOGENICITY ARE NOT REPORTED. ADDITIONAL INFORMATION MAY BE FOUND IN SECTION V. OTHER COMPONENTS MAY BE LISTED IF DEEMED APPROPRIATE.

IDENTITIES OF COMPONENTS LISTED GENERICALLY ARE DECLARED TRADE SECRET.

EXPOSURE RECOMMENDATIONS ARE FOR COMPONENTS. OSHA PERMISSIBLE EXPOSURE LIMITS (PELS) AND AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH) THRESHOLD LIMIT VALUES (TLVS) APPEAR ON THE LINE WITH THE COMPONENT IDENTIFICATION. OTHER RECOMMENDATIONS APPEAR AS FOOTNOTES.

### SECTION III
### PHYSICAL DATA

BOILING POINT: OF PRODUCT IF KNOWN. THE LOWEST VALUE OF THE COMPONENTS IS LISTED FOR MIXTURES.

VAPOR PRESSURE: OF PRODUCT IF KNOWN. THE HIGHEST VALUE OF THE COMPONENTS IS LISTED FOR MIXTURES.

SPECIFIC VAPOR DENSITY: COMPARED TO AIR = 1. IF SPECIFIC VAPOR DENSITY OF PRODUCT IS NOT KNOWN, THE VALUE IS EXPRESSED AS LIGHTER OR HEAVIER THAN AIR.

SPECIFIC GRAVITY: COMPARED TO WATER = 1. IF SPECIFIC GRAVITY OF PRODUCT IS NOT KNOWN. THE VALUE IS EXPRESSED AS LESS THAN OR GREATER THAN WATER.

PH: IF APPLICABLE.

PERCENT VOLATILES: PERCENTAGE OF MATERIAL WITH INITIAL BOILING POINT BELOW 425 DEGREES FAHRENHEIT.

EVAPORATION RATE: INDICATED AS FASTER OR SLOWER THAN ETHYL ETHER, UNLESS OTHERWISE STATED.

### SECTION IV
### FIRE AND EXPLOSION INFORMATION

FLASH POINT: METHOD IDENTIFIED.

EXPLOSION LIMITS: FOR PRODUCT IF KNOWN. THE LOWEST VALUE OF THE COMPONENTS IS LISTED FOR MIXTURES.

HAZARDOUS DECOMPOSITION PRODUCTS: KNOWN OR EXPECTED HAZARDOUS PRODUCTS RESULTING FROM HEATING, BURNING, OR OTHER REACTIONS.

### SECTION IV (CONT.)

EXTINGUISHING MEDIA: FOLLOWING NATIONAL FIRE PROTECTION ASSOCIATION CRITERIA.

FIREFIGHTING PROCEDURES: MINIMUM EQUIPMENT TO PROTECT FIREFIGHTERS FROM TOXIC PRODUCTS OF VAPORIZATION, COMBUSTION OR DECOMPOSITION IN FIRE SITUATIONS. OTHER FIREFIGHTING HAZARDS MAY ALSO BE INDICATED.

SPECIAL FIRE AND EXPLOSION HAZARDS: STATES HAZARDS NOT COVERED BY OTHER SECTIONS.

NFPA CODES: HAZARD RATINGS ASSIGNED BY THE NATIONAL FIRE PROTECTION ASSOCIATION.

### SECTION V
### HEALTH HAZARD DATA

PERMISSIBLE EXPOSURE LIMIT: FOR PRODUCT.

THRESHOLD LIMIT VALUE: FOR PRODUCT.

EFFECTS OF ACUTE OVEREXPOSURE: POTENTIAL LOCAL AND SYSTEMIC EFFECTS DUE TO SINGLE OR SHORT TERM OVEREXPOSURE TO THE EYES AND SKIN OR THROUGH INHALATION OR INGESTION.

EFFECTS OF CHRONIC OVEREXPOSURE: POTENTIAL LOCAL AND SYSTEMIC EFFECTS DUE TO REPEATED OR LONG TERM OVEREXPOSURE TO THE EYES AND SKIN OR THROUGH INHALATION OR INGESTION.

FIRST AID: PROCEDURES TO BE FOLLOWED WHEN DEALING WITH ACCIDENTAL OVEREXPOSURES.

PRIMARY ROUTE OF ENTRY: BASED ON PROPERTIES AND EXPECTED USE.

### SECTION VI
### REACTIVITY DATA

HAZARDOUS POLYMERIZATION: CONDITIONS TO AVOID TO PREVENT HAZARDOUS POLYMERIZATION RESULTING IN A LARGE RELEASE OF ENERGY.

STABILITY: CONDITIONS TO AVOID TO PREVENT HAZARDOUS OR VIOLENT DECOMPOSITION.

INCOMPATIBILITY: MATERIALS AND CONDITIONS TO AVOID TO PREVENT HAZARDOUS REACTIONS.

### SECTION VII
### SPILL OR LEAK PROCEDURES

REASONABLE PRECAUTIONS TO BE TAKEN AND METHODS OF CONTAINMENT, CLEAN-UP AND DISPOSAL. CONSULT FEDERAL, STATE AND LOCAL REGULATIONS FOR ACCEPTED PROCEDURES AND ANY REPORTING OR NOTIFICATION REQUIREMENTS.

### SECTION VIII
### PROTECTIVE EQUIPMENT TO BE USED

PROTECTIVE EQUIPMENT WHICH MAY BE NEEDED WHEN HANDLING THE PRODUCT.

### SECTION IX
### SPECIAL PRECAUTIONS OR OTHER COMMENTS

COVERS ANY RELEVANT POINTS NOT PREVIOUSLY MENTIONED.

### ADDITIONAL COMMENTS

CONTAINERS SHOULD BE EITHER RECONDITIONED BY CERTIFIED FIRMS OR PROPERLY DISPOSED OF BY APPROVED FIRMS. DISPOSAL OF CONTAINERS SHOULD BE IN ACCORDANCE WITH APPLICABLE LAWS AND REGULATIONS. "EMPTY" DRUMS SHOULD NOT BE GIVEN TO INDIVIDUALS. SERIOUS ACCIDENTS HAVE RESULTED FROM THE MISUSE OF "EMPTIED" CONTAINERS (DRUMS, PAILS, ETC.). REFER TO SECTIONS IV AND IX.

ROWE PAINT MFG. CO.

# MATERIAL SAFETY DATA SHEET

(APPROVED BY U S DEPARTMENT OF LABOR - "ESSENTIALLY SIMILAR" TO FORM OSHA-20

The information contained in this data sheet is the best and most current information available at ROWE PAINT MFG. CO. . This technical data is an aid to supplement good painting practices and common sense in the use of this product.

| | |
|---|---|
| TRADE NAME OF MATERIAL | Polyurethane Intermediate Coat — Component B |
| MANUFACTURER'S PRODUCT NO. | [illegible] — CHEMICAL NAME AND SYNONYMS |
| TYPE OF MATERIAL | CHEMICAL FAMILY: Aromatic Polyisocyanate |

## PAINTS, PRESERVATIVES & SOLVENTS

| PIGMENTS | % | TLV (Units) | SOLVENTS | % | TLV (Units) |
|---|---|---|---|---|---|
| None | | | Ethyl Acetate<br>N-Butyl Acetate<br>Glycol Ether EE<br>Aromatic Hydrocarbons | [illegible]<br>[illegible]<br>[illegible]<br>[illegible] | 400ppm<br>150ppm<br>5ppm<br>100ppm |
| **CATALYST** | | | **ADDITIVES** | | |
| Mondur CB-75 (See Attached Product #D-065) | 71.[illegible]% | | None | | |
| **VEHICLE** | | | **OTHERS** | | |
| None | | | None | | |

| | | | |
|---|---|---|---|
| BOILING POINT °F) | 168°-246°F | SPECIFIC GRAVITY (H2O=1) | 1.08 |
| VAPOR PRESSURE (mm Hg.) 76.00 mm @ | 20°C | PERCENT VOLATILE BY VOLUME (%) | 50.5% |
| VAPOR DENSITY (AIR=1) | over 1 | EVAPORATION RATE (N-BUAC=1) | over 1 |
| SOLUBILITY IN WATER | Insoluble | reacts with water to liberate $CO_2$ gas; EA-7.4% | |
| APPEARANCE AND ODOR | Clear/Yellow liquid: of solvent | | |

## I. PRODUCT IDENTIFICATION

| | |
|---|---|
| PRODUCT NAME.....: | Mondur CB-75 |
| PRODUCT CODE NUMBER.....: | D-065 |
| CHEMICAL FAMILY.....: | Aromatic Polyisocyanate |
| CHEMICAL NAME.....: | Toluene Diisocyanate based adduct |
| SYNONYMS.....: | Toluene diisocyanate prepolymer |
| T.S.C.A. STATUS.....: | OK |
| OSHA HAZARD COMMUNICATION STATUS.....: | This product is hazardous under the criteria of the federal OSHA Hazard Communication Standard 29 CFR 1910.1200. |
| CHEMICAL FORMULA.....: | Oligomeric resin, not applicable |

## II. HAZARDOUS INGREDIENTS

| COMPONENTS: | %: | OSHA-PEL | ACGIH-TLV |
|---|---|---|---|
| Ethyl Acetate (EA) (CAS# 141-78-6) | 25% | 400 ppm TWA | 400 ppm TWA |
| Aromatic Polyisocyanate | 75% | Not Established | Not Established |
| Toluene Diisocyanate (TDI) (CAS# 26471-62-5) | * | 0.02 ppm Ceiling | 0.005 ppm TWA<br>0.02 ppm STEL |

TDI residual monomer content is less than 0.7% based on resin solids.

## III. PHYSICAL DATA

| | |
|---|---|
| APPEARANCE.....: | Liquid |
| COLOR.....: | Clear yellow |
| ODOR.....: | Of solvent |
| MELT POINT/FREEZE POINT..: | Not Established |
| BOILING POINT.....: | EA - 170°F (77°C) |
| VAPOR PRESSURE.....: | EA - 86 mmHg @ 68°F (20°C) |
| VAPOR DENSITY (AIR=1)....: | EA - 3.0 |
| SPECIFIC GRAVITY.....: | 1.19 |
| BULK DENSITY.....: | 9.9 lbs/gal |
| SOLUBILITY IN WATER.....: | Isocyanate - Insoluble, reacts with water to liberate $CO_2$ gas; EA - 7.4% |
| % VOLATILE BY VOLUME.....: | About 34% |

## IV. FIRE & EXPLOSION DATA

FLASH POINT °F(°C).....: 30°F (-1°C) TAG Closed Cup (ASTM D56)
FLAMMABLE LIMITS - EA
Lel.....: 2.2
Uel.....: 11.0
EXTINGUISHING MEDIA.....: Dry chemical (e.g. monoammonium phosphate, potassium sulfate, and potassium chloride), carbon dioxide
SPECIAL FIRE FIGHTING PROCEDURES/UNUSUAL FIRE OR EXPLOSION HAZARDS:
Full emergency equipment with self-contained breathing apparatus and full protective clothing (such as rubber gloves, boots, bands around legs, arms and waist) should be worn by firefighters. No skin surface should be exposed. During a fire, TDI vapors and other irritating, highly toxic gases may be generated by thermal decomposition or combustion. (See Section VIII). Closed container may explode when exposed to extreme heat or burst when contaminated with water ($CO_2$ evolved). Solvent vapors may be heavier than air. Under conditions of stagnant air, vapors may build up and travel along the ground to an ignition source which may result in a flash back to the source of the vapors.

## V. HUMAN HEALTH DATA

PRIMARY ROUTE(S) OF EXPOSURE.....: Inhalation, Skin Contact, Eyes
HUMAN EFFECTS AND SYMPTOMS OF OVEREXPOSURE
INHALATION

Acute Exposure: TDI vapors or mist at concentrations above the TLV can irritate (burning sensation) the mucous membranes in the respiratory tract (nose, throat, lungs) causing runny nose, sore throat, coughing, chest discomfort, shortness of breath and reduced lung function (breathing obstruction). Persons with a preexisting, nonspecific bronchial hyperreactivity can respond to concentrations below the TLV with similar symptoms as well as asthma attack. Exposure well above the TLV may lead to bronchitis, bronchial spasm and pulmonary edema (fluid in lungs). These effects are usually reversible. Chemical or hypersensitive pneumonitis, with flu-like symptoms (e.g., fever, chills), has also been reported. These symptoms can be delayed up to several hours after exposure.

Solvent vapors are irritating to the eyes, nose, throat and respiratory tract resulting in red, itchy eyes, dryness of the throat and tightness in the chest. Other possible symptoms of overexposure include headache, nausea, narcosis, fatigue and loss of appetite. Ethyl Acetate odor may be objectionable at 200 ppm and is mildly irritating to the eyes, nose and throat at 400 ppm. At concentrations in excess of 13,000 ppm Ethyl Acetate is only mildly narcotic.

Chronic Exposure: As a result of previous repeated overexposures or a single large dose, certain individuals may develop isocyanate sensitization (chemical asthma) which will cause them to react to a later exposure to isocyanate at levels well below the TLV. These symptoms, which can include chest tightness, wheezing, cough, shortness of breath or asthmatic attack, could be immediate or delayed up to several hours

after exposure. Similar to many non-specific asthmatic responses, there are reports that once sensitized an individual can experience these symptoms upon exposure to dust, cold air or other irritants. This increased lung sensitivity can persist for weeks and in severe cases for several years. Chronic overexposure to isocyanate has also been reported to cause lung damage (including decrease in lung function) which may be permanent. Sensitization can either be temporary or permanent.

Chronic exposure to organic solvents has been associated with various neurotoxic effects including permanent brain and nervous system damage. Symptoms include loss of memory, loss of intellectual ability and loss of coordination.

SKIN CONTACT

Acute Exposure: Isocyanates react with skin protein and moisture and can cause irritation which may include the following symptoms: reddening, swelling, rash, scaling or blistering. Cured material is difficult to remove.

Repeated or prolonged skin contact with the solvent can result in dry, defatted and cracked skin causing increased susceptibility to infection. In addition, dermatitis and skin rash and redness may occur from skin contact. EA does not readily penetrate the skin to cause systemic toxic effects.

Chronic: Prolonged contact can cause reddening, swelling, rash, scaling, blistering, and, in some cases, skin sensitization. Individuals who have developed a skin sensitization can develop these symptoms as a result of contact with very small amounts of liquid material or as a result of exposure to vapor.

EYE CONTACT

Acute Exposure: Liquid, aerosols or vapors are severely irritating and can cause pain, tearing, reddening and swelling. If left untreated, corneal damage can occur and injury is slow to heal. However, damage is usually reversible. See Section VI for treatment.

Chronic Exposure: Prolonged vapor contact may cause conjunctivitis.

INGESTION

Acute Exposure: Can result in irritation in the mouth, stomach tissue and digestive tract. Symptoms can include sore throat, abdominal pain, nausea, vomiting and diarrhea. Vomiting may cause aspiration resulting in chemical pneumonitis.

Chronic Exposure: None known.

MEDICAL CONDITIONS

AGGRAVATED BY EXPOSURE..: Asthma, other respiratory disorders (bronchitis, emphysema, bronchial hyperreactivity), skin allergies, eczema.

CARCINOGENICITY

NTP.....: The National Toxicology Program reported that TDI caused an increase in the number of tumors in exposed rats over those counted in non-exposed rats. The TDI was administered in corn-oil and introduced into the stomach through a tube. Based on this study, the NTP has listed TDI as a substance that may reasonably be anticipated to be a carcinogen in its Fourth Annual Report on Carcinogens..

## V. HUMAN HEALTH DATA (Continued)

IARC.....: IARC has announced that it will list TDI as as substance for which there is sufficient evidence for its carcinogenicity in experimental animals but inadequate evidence for the carcinogenicity of TDI to humans (IARC Monograph 39).

OSHA.....: Not listed.

OTHER.....: No carcinogenic activity was observed in lifetime inhalation studies in rats and mice (International Isocyanate Institute).

EXPOSURE LIMITS - Not established for the product as a whole. Refer to Section II for exposure limits of the hazardous constituents.

## VI. EMERGENCY & FIRST AID PROCEDURES

EYE CONTACT.....: Flush with clean, lukewarm water (low pressure) or at least 15 minutes holding eyelids open all the time, and obtain medical attention. Refer individual to an opthalmologist for immediate follow-up.

SKIN CONTACT.....: Remove contaminated clothing immediately. Wash affected areas thoroughly with soap or tincture of green soap and water for at least 15 minutes. Wash contaminated clothing thoroughly before reuse. For severe exposures, get under safety shower after removing clothing, get medical attention, and consult physician.

INHALATION.....: Move to an area free from risk of further exposure. Administer oxygen or artificial respiration as needed. Obtain medical attention. Asthmatic-type symptoms may develop and may be immediate or delayed up to several hours. Consult physician.

INGESTION.....: DO NOT INDUCE VOMITING. Give a glass of milk or water to drink. DO NOT GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON. Consult physician.

NOTE TO PHYSICIAN.....: Eyes: Stain for evidence of corneal injury. If cornea is burned, instill antibiotic steroid preparation frequently. Workplace vapors have produced reversible corneal epithelial edema impairing vision. Skin: Treat as contact dermatitis. If burned, treat as thermal burn. Respiratory: Treatment is essentially symptomatic.

## VII. EMPLOYEE PROTECTION RECOMMENDATIONS

EYE PROTECTION.....: Liquid chemical goggles or full-face shield. Contact lenses should not be worn.

SKIN PROTECTION.....: Chemical resistant gloves (butyl rubber, nitrile rubber). Cover as much of the exposed skin area as possible with appropriate clothing. If skin creams are used, keep the area covered by the cream to a minimum.

VENTILATION AND
RESPIRATORY PROTECTION..: Exhaust ventilation sufficient to keep the airborne concentrations of the solvents and TDI below their respective TLVs must be utilized. Exhaust air may need to be cleaned by scrubbers or filters to reduce environmental contamination. In addition, a respirator that is recommended or approved for use in isocyanate containing environments (air purifying or fresh air supplied) may be necessary. Consider type of

## VII. EMPLOYEE PROTECTION RECOMMENDATIONS (Continued)

application and environmental concentrations. Observe OSHA regulations for respirator use (29 CFR 1910.134). In spray applications, when the airborne isocyanate monomer concentrations are known to be below 0.2 ppm and if the polyisocyanate (polymeric, oligomer) concentrations are known to be below 10 $mg/m^3$, a properly fitted air-purifying (combination organic vapor and particulate) respirator, proven by test to be effective in isocyanate containing spray paint environments, will provide sufficient protection. The use of a positive pressure supplied air respirator is mandatory when: airborne isocyanate concentrations are not known, either of the above guidelines are exceeded, or if spraying is performed in a confined space or area with limited ventilation.

It is possible to be exposed to airborne solvent or isocyanate vapors even during non-spray operations such as mixing, and brush or roller application, depending on the conditions of application. For example, heating of material or application to a hot substrate may increase emissions from the coating. Therefore, when airborne concentrations during such non-spray operations exceed the suggested TLV of 0.02 ppm for isocyanate monomer, but are below 0.2 ppm, at least an air purifying (organic vapor) respirator is required. If airborne concentrations are unknown or exceed 0.2 ppm; or if operations are performed in a confined space, a supplied air respirator must be worn. In addition, solvent concentrations should be considered when determining the selection and use of a respirator.

Refer to Patty's Industrial Hygiene and Toxicology, Volume 1 (3rd edition) Chapter 17 and Volume III (1st edition) Chapter 3, for guidance concerning appropriate air sampling strategy to determine airborne concentrations.

**MEDICAL SURVEILLANCE.....:** Medical supervision of all employees who handle or come in contact with TDI is recommended. These should include preemployment and periodic medical examinations with respiratory function tests (FEV, FVC as a minimum). Persons with asthmatic-type conditions, chronic bronchitis, other chronic respiratory diseases or recurrent skin eczema or sensitization should be excluded from working with TDI. Once a person is diagnosed as being sensitized to TDI, no further exposure can be permitted.

**MONITORING.....:** TDI, polyisocyanate and solvent exposure levels must be monitored by accepted monitoring techniques to ensure that the TLVs are not exceeded. (Contact Mobay for guidance). See Volume 1 (Chapter 17) and Volume 3 (Chapter 3) in Patty's Industrial Hygiene and Toxicology for sampling strategy.

**OTHER.....:** Safety showers and eyewash stations should be available. Educate and train employees in safe use of product. Follow all label instructions.

## VIII. REACTIVITY DATA

STABILITY.....: Stable under normal conditions.
POLYMERIZATION.....: None under normal conditions.
INCOMPATIBILITY
(MATERIALS TO AVOID)....: Avoid contact with water, alcohols, amines, strong bases, metal compounds or surface active materials. This product contains trimethylol propane and should not be combined with phosphorus containing materials.
HAZARDOUS DECOMPOSITION
PRODUCTS.....: By fire: $CO_2$, CO, oxides of nitrogen, HCN, TDI.

## IX. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:
Evacuate non-essential personnel. Remove all sources of ignition. Ventilate the area. Equip clean-up crew with appropriate protective equipment (i.e., clothing, respiratory, etc. See Employee Protection Recommendations). Dike or impound spilled material and control further spillage if feasible. Notify appropriate authorities if necessary. Cover spill with sawdust, vermiculite, Fuller's earth or other absorbent material; pour liquid decontaminant over spillage and allow to react at least 10 min., collect material in open containers and add further amounts of decontamination solution. Remove containers to safe place. Cover loosely. Wash down area with liquid decontaminant and flush spill area with water.

Decontamination solutions: Ammonium hydroxide (0-10%), detergent (2-5%) and balance water; or solution of Union Carbide's Tergitol TMN-10 (20%) and water (80%).
CERCLA (SUPERFUND) REPORTABLE QUANTITY: TDI - 100 lbs.; EA - 5000 lbs.
WASTE DISPOSAL METHOD: Follow all federal, state or local regulations. TDI must be disposed of in a permitted incinerator or landfill. Incineration is the preferred method for liquids. Solids are usually incinerated or landfilled. Empty containers must be handled with care due to product residue. Decontaminate containers prior to disposal. Empty decontaminated containers should be crushed to prevent reuse. DO NOT HEAT OR CUT EMPTY CONTAINER WITH ELECTRIC OR GAS TORCH. (See Sections IV and VIII). Vapors and gases may be highly toxic.
RCRA STATUS.....: Mondur CB-75 is a hazardous waste due to its ignitability (EPA Hazardous Waste Number D001).

## X. SPECIAL PRECAUTIONS & STORAGE DATA

STORAGE TEMPERATURE
(MIN./MAX.).....: 32°F (0°C)/122°F (50°C)
AVERAGE SHELF LIFE.....: 12 months at 77°F (25°C)
SPECIAL SENSITIVITY
(HEAT, LIGHT, MOISTURE).: If container is exposed to high heat, 375°F (177°C) it can be pressurized and possibly rupture. The isocyanates react slowly with water to form polyureas and liberate $CO_2$ gas. This gas can cause sealed containers to expand and possibly rupture.

## X. SPECIAL PRECAUTIONS & STORAGE DATA (Continued)

PRECAUTIONS TO BE TAKEN

IN HANDLING AND STORING.: Keep away from heat, sparks or open flame. Ground container during storage and transfer operations. Store in tightly closed containers to prevent moisture contamination. Do not reseal if contamination is suspected. Prevent all contact. Do not breathe the vapors. Warning properties of isocyanates (irritation of the eyes, nose and throat or odor) are not adequate to prevent chronic overexposure from inhalation. This material can produce asthmatic sensitization upon either single inhalation exposure to a relatively high concentration or upon repeated inhalation exposures to lower concentrations. Exposure to vapors of heated TDI can be extremely dangerous. Employee education and training in safe handling of this product are required under the OSHA Hazard Communication Standard.

## XI. SHIPPING DATA

| | |
|---|---|
| D.O.T. SHIPPING NAME.....: | Flammable Liquid NOS |
| TECHNICAL SHIPPING NAME...: | Polyisocyanate, contains toluene diisocyanate and Ethyl Acetate |
| D.O.T. HAZARD CLASS.....: | Flammable Liquid |
| UN/NA NO.....: | UN 1993 |
| PRODUCT REPORTABLE QTY....: | 19,000 lbs. |
| D.O.T. LABELS REQUIRED....: | Flammable Liquid |
| D.O.T. PLACARDS.....: | Flammable |
| FRT. CLASS BULK.....: | Isocyanate |
| FRT. CLASS PKG.....: | Chemicals NOI (Isocyanate) (NMFC 60000) |
| PRODUCT LABEL.....: | Mondur CB-75 |

## XII. ANIMAL TOXICITY DATA

ANIMAL TOXICITY - 100% solids polyisocyanate resin.

ORAL, LD50
(INGESTION).....: Greater than 25 g/kg (Rat)

DERMAL, LD50
(SKIN CONTACT).....: Greater than 6.5 g/kg (Rabbit)

EYE EFFECTS.....: Mechanical irritation observed (Rabbit)

SKIN EFFECTS.....: Non-irritating (Rabbit)

ANIMAL TOXICITY - Ethyl Acetate

ORAL, LD50.....: 5.6 g/kg (Rat)

INHALATION, LC50.....: Greater than 8000 ppm (Rat) - 8000 ppm caused no deaths; 16,000 ppm killed all test animals.

DERMAL.....: Greater than 18 g/kg (Rabbit)

OTHER.....: Guinea pigs exposed to 2000 ppm for 4 hr/day, 6 days/week for 65 exposures showed no ill effects.

ANIMAL TOXICITY - TDI

SENSITIZATION.....: Skin sensitizer in guinea pigs. One study (available upon request) with guinea pigs reported that repeated skin contact with TDI caused respiratory sensitization.

SUB-ACUTE/SUB-CHRONIC.....: Animal tests indicated that TDI inhalation caused irritation of the mucous membranes of the respiratory tract.

## XII. ANIMAL TOXICITY DATA (Continued)

CHRONIC.....: In lifetime inhalation studies conducted by Hazelton Labs for the International Isocyanate Institute, TDI did not demonstrate carcinogenic (cancer causing) activity in rats or mice. In this study, exposure to 0.05 to 0.15 ppm resulted in irritation of the mucous membranes of the respiratory tract.

The National Toxicology Program (NTP) reported that TDI administered by gavage caused an increase in tumors in exposed animals. Based on this study TDI has been listed by NTP and IARC.

MUTAGENIC TESTS.....: Results of mutagenic (genotoxic) studies are conflicting with some tests positive and others negative.

## XIII. APPROVALS

REASON FOR ISSUE.....: Revision
APPROVED BY.....: Paul D. Ziegler
TITLE.....: Manager, Product Safety

ROWE PAINT MFG. CO.

# MATERIAL SAFETY DATA SHEET

(APPROVED BY U S DEPARTMENT OF LABOR - "ESSENTIALLY SIMILAR" TO FORM OSHA-20

The information contained in this data sheet is the best and most current information available at ROWE PAINT MFG. CO. . This technical data is an aid to supplement good painting practices and common sense in the use of this product.

| | |
|---|---|
| TRADE NAME OF MATERIAL | Polyurethane Topcoat Component A |
| MANUFACTURER'S PRODUCT NO. | V-3634 |
| TYPE OF MATERIAL | CHEMICAL NAME AND SYNONYMS Polyester Resin/Hydroxy |
| | CHEMICAL FAMILY Terminated Linear Polyester Polyol |

## PAINTS, PRESERVATIVES & SOLVENTS

| PIGMENTS | % | TLV (Units) | SOLVENTS | % | TLV (Units) |
|---|---|---|---|---|---|
| Non-Hazardous | | | Glycol Ether EE | 6.6% | 5ppm |
| | | | N-Butyl Acetate | 13.7% | 150ppm |
| | | | Ethyl Acetate | 10.3% | 400ppm |
| | | | Aromatic Hydrocarbons | 4.3% | 100ppm |
| CATALYST | | | ADDITIVES | | |
| None | | | Non-Hazardous | | |
| VEHICLE | | | OTHERS | | |
| Non-Hazardous | | | None | | |

| | | | |
|---|---|---|---|
| BOILING POINT °F) | 168°-262°F | SPECIFIC GRAVITY (H2O=1) | 1.36 |
| VAPOR PRESSURE (mm Hg.) 76.00 mmhg | @ 20°F | PERCENT VOLATILE BY VOLUME (%) | 51% |
| VAPOR DENSITY (AIR=1) | Over 1 | EVAPORATION RATE (N-BUAC=1) | Over 1 |
| SOLUBILITY IN WATER | Negligible | | |
| APPEARANCE AND ODOR White pigmented paint; Acetate odor | | | |

## SECTION IV-FIRE AND EXPLOSION INFORMATION

FLASH POINT ( 26.0 DEG F / -3.3 DEG C)

EXPLOSIVE LIMIT (PRODUCT) LOWER - 2.2%

EXTINGUISHING MEDIA: ALCOHOL FOAM OR CARBON DIOXIDE OR DRY CHEMICAL

HAZARDOUS DECOMPOSITION PRODUCTS: MAY FORM TOXIC MATERIALS:, CARBON DIOXIDE AND CARBON MONOXIDE, VARIOUS HYDROCARBONS, ETC.

FIREFIGHTING PROCEDURES, WEAR SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE WHEN FIGHTING FIRES.

SPECIAL FIRE & EXPLOSION HAZARDS, VAPORS ARE HEAVIER THAN AIR AND MAY TRAVEL ALONG THE GROUND OR MAY BE MOVED BY VENTILATION AND IGNITED BY PILOT LIGHTS, OTHER FLAMES, SPARKS, HEATERS, SMOKING, ELECTRIC MOTORS, STATIC DISCHARGE, OR OTHER IGNITION SOURCES AT LOCATIONS DISTANT FROM MATERIAL HANDLING POINT.

NEVER USE WELDING OR CUTTING TORCH ON OR NE

C-21

ROWE PAINT MFG. CO.

# MATERIAL SAFETY DATA SHEET

(APPROVED BY U S DEPARTMENT OF LABOR - "ESSENTIALLY SIMILAR" TO FORM OSHA-20

The information contained in this data sheet is the best and most current information available at ROWE PAINT MFG. CO. . This technical data is an aid to supplement good painting practices and common sense in the use of this product.

| | |
|---|---|
| TRADE NAME OF MATERIAL | Polyurethane Topcoat — Component B |
| MANUFACTURER'S PRODUCT NO. | [illegible]-363- — CHEMICAL NAME AND SYNONYMS |
| TYPE OF MATERIAL | CHEMICAL FAMILY Aromatic Polyisocyanate |

## PAINTS, PRESERVATIVES & SOLVENTS

| PIGMENTS | % | TLV (Units) | SOLVENTS | % | TLV (Units) |
|---|---|---|---|---|---|
| None | | | Ethyl Acetate | 5.6% | 400ppm |
| | | | N-Butyl Acetate | 6.4% | 150ppm |
| | | | Glycol Ether EE | 3.7% | 5ppm |
| | | | Aromatic Hydrocarbons | 1.9% | 100ppm |
| CATALYST | | | ADDITIVES | | |
| Mondur CB-75 (See Attached Product | 81.2% #D-065) | | None | | |
| VEHICLE | | | OTHERS | | |
| None | | | None | | |

| | | | |
|---|---|---|---|
| BOILING POINT °F) | 168°-262°F | SPECIFIC GRAVITY (H2O=1) | 1.10 |
| VAPOR PRESSURE (mm Hg.) 76.00mm | @ 20°C | PERCENT VOLATILE BY VOLUME (%) | 42.4% |
| VAPOR DENSITY (AIR=1) | over 1 | EVAPORATION RATE (N-BUAC=1) | over 1 |
| SOLUBILITY IN WATER | Insoluble | reacts with water to liberate $CO_2$ gas; | |
| APPEARANCE AND ODOR Clear/Yellow Liquid; of solvent | | | EA-6.-3 |

## I. PRODUCT IDENTIFICATION

PRODUCT NAME.....: Mondur CB-75
PRODUCT CODE NUMBER.....: D-065
CHEMICAL FAMILY.....: Aromatic Polyisocyanate
CHEMICAL NAME.....: Toluene Diisocyanate based adduct
SYNONYMS.....: Toluene diisocyanate prepolymer
T.S.C.A. STATUS.....: OK
OSHA HAZARD COMMUNICATION STATUS.....: This product is hazardous under the criteria of the federal OSHA Hazard Communication Standard 29 CFR 1910.1200.
CHEMICAL FORMULA.....: Oligomeric resin, not applicable

## II. HAZARDOUS INGREDIENTS

| COMPONENTS: | %: | OSHA-PEL | ACGIH-TLV |
|---|---|---|---|
| Ethyl Acetate (EA) (CAS# 141-78-6) | 25% | 400 ppm TWA | 400 ppm TWA |
| Aromatic Polyisocyanate | 75% | Not Established | Not Established |
| Toluene Diisocyanate (TDI) (CAS# 26471-62-5) | * | 0.02 ppm Ceiling | 0.005 ppm TWA<br>0.02 ppm STEL |

TDI residual monomer content is less than 0.7% based on resin solids.

## III. PHYSICAL DATA

APPEARANCE.....: Liquid
COLOR.....: Clear yellow
ODOR.....: Of solvent
MELT POINT/FREEZE POINT..: Not Established
BOILING POINT.....: EA - 170°F (77°C)
VAPOR PRESSURE.....: EA - 86 mmHg @ 68°F (20°C)
VAPOR DENSITY (AIR=1)....: EA - 3.0
SPECIFIC GRAVITY.....: 1.19
BULK DENSITY.....: 9.9 lbs/gal
SOLUBILITY IN WATER.....: Isocyanate - Insoluble, reacts with water to liberate $CO_2$ gas; EA - 7.4%
% VOLATILE BY VOLUME.....: About 34%

## IV. FIRE & EXPLOSION DATA

FLASH POINT °F(°C).....: 30°F (-1°C) TAG Closed Cup (ASTM D56)
FLAMMABLE LIMITS - EA
Lel.....: 2.2
Uel.....: 11.0
EXTINGUISHING MEDIA.....: Dry chemical (e.g. monoammonium phosphate, potassium sulfate, and potassium chloride), carbon dioxide
SPECIAL FIRE FIGHTING PROCEDURES/UNUSUAL FIRE OR EXPLOSION HAZARDS:
Full emergency equipment with self-contained breathing apparatus and full protective clothing (such as rubber gloves, boots, bands around legs, arms and waist) should be worn by firefighters. No skin surface should be exposed. During a fire, TDI vapors and other irritating, highly toxic gases may be generated by thermal decomposition or combustion. (See Section VIII). Closed container may explode when exposed to extreme heat or burst when contaminated with water ($CO_2$ evolved). Solvent vapors may be heavier than air. Under conditions of stagnant air, vapors may build up and travel along the ground to an ignition source which may result in a flash back to the source of the vapors.

## V. HUMAN HEALTH DATA

PRIMARY ROUTE(S) OF EXPOSURE.....: Inhalation, Skin Contact, Eyes
HUMAN EFFECTS AND SYMPTOMS OF OVEREXPOSURE
INHALATION

Acute Exposure: TDI vapors or mist at concentrations above the TLV can irritate (burning sensation) the mucous membranes in the respiratory tract (nose, throat, lungs) causing runny nose, sore throat, coughing, chest discomfort, shortness of breath and reduced lung function (breathing obstruction). Persons with a preexisting, nonspecific bronchial hyperreactivity can respond to concentrations below the TLV with similar symptoms as well as asthma attack. Exposure well above the TLV may lead to bronchitis, bronchial spasm and pulmonary edema (fluid in lungs). These effects are usually reversible. Chemical or hypersensitive pneumonitis, with flu-like symptoms (e.g., fever, chills), has also been reported. These symptoms can be delayed up to several hours after exposure.

Solvent vapors are irritating to the eyes, nose, throat and respiratory tract resulting in red, itchy eyes, dryness of the throat and tightness in the chest. Other possible symptoms of overexposure include headache, nausea, narcosis, fatigue and loss of appetite. Ethyl Acetate odor may be objectionable at 200 ppm and is mildly irritating to the eyes, nose and throat at 400 ppm. At concentrations in excess of 13,000 ppm Ethyl Acetate is only mildly narcotic.

Chronic Exposure: As a result of previous repeated overexposures or a single large dose, certain individuals may develop isocyanate sensitization (chemical asthma) which will cause them to react to a later exposure to isocyanate at levels well below the TLV. These symptoms, which can include chest tightness, wheezing, cough, shortness of breath or asthmatic attack, could be immediate or delayed up to several hours

after exposure. Similar to many non-specific asthmatic responses, there are reports that once sensitized an individual can experience these symptoms upon exposure to dust, cold air or other irritants. This increased lung sensitivity can persist for weeks and in severe cases for several years. Chronic overexposure to isocyanate has also been reported to cause lung damage (including decrease in lung function) which may be permanent. Sensitization can either be temporary or permanent.

Chronic exposure to organic solvents has been associated with various neurotoxic effects including permanent brain and nervous system damage. Symptoms include loss of memory, loss of intellectual ability and loss of coordination.

SKIN CONTACT

Acute Exposure: Isocyanates react with skin protein and moisture and can cause irritation which may include the following symptoms: reddening, swelling, rash, scaling or blistering. Cured material is difficult to remove.

Repeated or prolonged skin contact with the solvent can result in dry, defatted and cracked skin causing increased susceptibility to infection. In addition, dermatitis and skin rash and redness may occur from skin contact. EA does not readily penetrate the skin to cause systemic toxic effects.

Chronic: Prolonged contact can cause reddening, swelling, rash, scaling, blistering, and, in some cases, skin sensitization. Individuals who have developed a skin sensitization can develop these symptoms as a result of contact with very small amounts of liquid material or as a result of exposure to vapor.

EYE CONTACT

Acute Exposure: Liquid, aerosols or vapors are severely irritating and can cause pain, tearing, reddening and swelling. If left untreated, corneal damage can occur and injury is slow to heal. However, damage is usually reversible. See Section VI for treatment.

Chronic Exposure: Prolonged vapor contact may cause conjunctivitis.

INGESTION

Acute Exposure: Can result in irritation in the mouth, stomach tissue and digestive tract. Symptoms can include sore throat, abdominal pain, nausea, vomiting and diarrhea. Vomiting may cause aspiration resulting in chemical pneumonitis.

Chronic Exposure: None known.

MEDICAL CONDITIONS

AGGRAVATED BY EXPOSURE..: Asthma, other respiratory disorders (bronchitis, emphysema, bronchial hyperreactivity), skin allergies, eczema.

CARCINOGENICITY

NTP.....: The National Toxicology Program reported that TDI caused an increase in the number of tumors in exposed rats over those counted in non-exposed rats. The TDI was administered in corn-oil and introduced into the stomach through a tube. Based on this study, the NTP has listed TDI as a substance that may reasonably be anticipated to be a carcinogen in its Fourth Annual Report on Carcinogens.

## V. HUMAN HEALTH DATA (Continued)

IARC.....: IARC has announced that it will list TDI as as substance for which there is sufficient evidence for its carcinogenicity in experimental animals but inadequate evidence for the carcinogenicity of TDI to humans (IARC Monograph 39).
OSHA.....: Not listed.
OTHER.....: No carcinogenic activity was observed in lifetime inhalation studies in rats and mice (International Isocyanate Institute).

EXPOSURE LIMITS - Not established for the product as a whole. Refer to Section II for exposure limits of the hazardous constituents.

## VI. EMERGENCY & FIRST AID PROCEDURES

EYE CONTACT.....: Flush with clean, lukewarm water (low pressure) or at least 15 minutes holding eyelids open all the time, and obtain medical attention. Refer individual to an opthalmologist for immediate follow-up.
SKIN CONTACT.....: Remove contaminated clothing immediately. Wash affected areas thoroughly with soap or tincture of green soap and water for at least 15 minutes. Wash contaminated clothing thoroughly before reuse. For severe exposures, get under safety shower after removing clothing, get medical attention, and consult physician.
INHALATION.....: Move to an area free from risk of further exposure. Administer oxygen or artificial respiration as needed. Obtain medical attention. Asthmatic-type symptoms may develop and may be immediate or delayed up to several hours. Consult physician.
INGESTION.....: DO NOT INDUCE VOMITING. Give a glass of milk or water to drink. DO NOT GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON. Consult physician.
NOTE TO PHYSICIAN.....: Eyes: Stain for evidence of corneal injury. If cornea is burned, instill antibiotic steroid preparation frequently. Workplace vapors have produced reversible corneal epithelial edema impairing vision. Skin: Treat as contact dermatitis. If burned, treat as thermal burn. Respiratory: Treatment is essentially symptomatic.

## VII. EMPLOYEE PROTECTION RECOMMENDATIONS

EYE PROTECTION.....: Liquid chemical goggles or full-face shield. Contact lenses should not be worn.
SKIN PROTECTION.....: Chemical resistant gloves (butyl rubber, nitrile rubber). Cover as much of the exposed skin area as possible with appropriate clothing. If skin creams are used, keep the area covered by the cream to a minimum.
VENTILATION AND
RESPIRATORY PROTECTION..: Exhaust ventilation sufficient to keep the airborne concentrations of the solvents and TDI below their respective TLVs must be utilized. Exhaust air may need to be cleaned by scrubbers or filters to reduce environmental contamination. In addition, a respirator that is recommended or approved for use in isocyanate containing environments (air purifying or fresh air supplied) may be necessary. Consider type of

application and environmental concentrations. Observe OSHA regulations for respirator use (29 CFR 1910.134). In spray applications, when the airborne isocyanate monomer concentrations are known to be below 0.2 ppm and if the polyisocyanate (polymeric, oligomer) concentrations are known to be below 10 mg/m$^3$, a properly fitted air-purifying (combination organic vapor and particulate) respirator, proven by test to be effective in isocyanate containing spray paint environments, will provide sufficient protection. The use of a positive pressure supplied air respirator is mandatory when: airborne isocyanate concentrations are not known, either of the above guidelines are exceeded, or if spraying is performed in a confined space or area with limited ventilation.

It is possible to be exposed to airborne solvent or isocyanate vapors even during non-spray operations such as mixing, and brush or roller application, depending on the conditions of application. For example, heating of material or application to a hot substrate may increase emissions from the coating. Therefore, when airborne concentrations during such non-spray operations exceed the suggested TLV of 0.02 ppm for isocyanate monomer, but are below 0.2 ppm, at least an air purifying (organic vapor) respirator is required. If airborne concentrations are unknown or exceed 0.2 ppm; or if operations are performed in a confined space, a supplied air respirator must be worn. In addition, solvent concentrations should be considered when determining the selection and use of a respirator.

Refer to Patty's Industrial Hygiene and Toxicology, Volume 1 (3rd edition) Chapter 17 and Volume III (1st edition) Chapter 3, for guidance concerning appropriate air sampling strategy to determine airborne concentrations.

**MEDICAL SURVEILLANCE.....:** Medical supervision of all employees who handle or come in contact with TDI is recommended. These should include preemployment and periodic medical examinations with respiratory function tests (FEV, FVC as a minimum). Persons with asthmatic-type conditions, chronic bronchitis, other chronic respiratory diseases or recurrent skin eczema or sensitization should be excluded from working with TDI. Once a person is diagnosed as being sensitized to TDI, no further exposure can be permitted.

**MONITORING.....:** TDI, polyisocyanate and solvent exposure levels must be monitored by accepted monitoring techniques to ensure that the TLVs are not exceeded. (Contact Mobay for guidance). See Volume 1 (Chapter 17) and Volume 3 (Chapter 3) in Patty's Industrial Hygiene and Toxicology for sampling strategy.

**OTHER.....:** Safety showers and eyewash stations should be available. Educate and train employees in safe use of product. Follow all label instructions.

## VIII. REACTIVITY DATA

STABILITY.....: Stable under normal conditions.
POLYMERIZATION.....: None under normal conditions.
INCOMPATIBILITY
(MATERIALS TO AVOID)....: Avoid contact with water, alcohols, amines, strong bases, metal compounds or surface active materials. This product contains trimethylol propane and should not be combined with phosphorus containing materials.
HAZARDOUS DECOMPOSITION
PRODUCTS.....: By fire: $CO_2$, CO, oxides of nitrogen, HCN, TDI.

## IX. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:
Evacuate non-essential personnel. Remove all sources of ignition. Ventilate the area. Equip clean-up crew with appropriate protective equipment (i.e., clothing, respiratory, etc. See Employee Protection Recommendations). Dike or impound spilled material and control further spillage if feasible. Notify appropriate authorities if necessary. Cover spill with sawdust, vermiculite, Fuller's earth or other absorbent material; pour liquid decontaminant over spillage and allow to react at least 10 min., collect material in open containers and add further amounts of decontamination solution. Remove containers to safe place. Cover loosely. Wash down area with liquid decontaminant and flush spill area with water.

Decontamination solutions: Ammonium hydroxide (0-10%), detergent (2-5%) and balance water; or solution of Union Carbide's Tergitol TMN-10 (20%) and water (80%).
CERCLA (SUPERFUND) REPORTABLE QUANTITY: TDI - 100 lbs.; EA - 5000 lbs.
WASTE DISPOSAL METHOD: Follow all federal, state or local regulations. TDI must be disposed of in a permitted incinerator or landfill. Incineration is the preferred method for liquids. Solids are usually incinerated or landfilled. Empty containers must be handled with care due to product residue. Decontaminate containers prior to disposal. Empty decontaminated containers should be crushed to prevent reuse. DO NOT HEAT OR CUT EMPTY CONTAINER WITH ELECTRIC OR GAS TORCH. (See Sections IV and VIII). Vapors and gases may be highly toxic.
RCRA STATUS.....: Mondur CB-75 is a hazardous waste due to its ignitability (EPA Hazardous Waste Number D001).

## X. SPECIAL PRECAUTIONS & STORAGE DATA

STORAGE TEMPERATURE
(MIN./MAX.).....: 32°F (0°C)/122°F (50°C)
AVERAGE SHELF LIFE.....: 12 months at 77°F (25°C)
SPECIAL SENSITIVITY
(HEAT, LIGHT, MOISTURE).: If container is exposed to high heat, 375°F (177°C) it can be pressurized and possibly rupture. The isocyanates react slowly with water to form polyureas and liberate $CO_2$ gas. This gas can cause sealed containers to expand and possibly rupture.

## X. SPECIAL PRECAUTIONS & STORAGE DATA (Continued)

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING.: Keep away from heat, sparks or open flame. Ground container during storage and transfer operations. Store in tightly closed containers to prevent moisture contamination. Do not reseal if contamination is suspected. Prevent all contact. Do not breathe the vapors. Warning properties of isocyanates (irritation of the eyes, nose and throat or odor) are not adequate to prevent chronic overexposure from inhalation. This material can produce asthmatic sensitization upon either single inhalation exposure to a relatively high concentration or upon repeated inhalation exposures to lower concentrations. Exposure to vapors of heated TDI can be extremely dangerous. Employee education and training in safe handling of this product are required under the OSHA Hazard Communication Standard.

## XI. SHIPPING DATA

| | |
|---|---|
| D.O.T. SHIPPING NAME.....: | Flammable Liquid NOS |
| TECHNICAL SHIPPING NAME...: | Polyisocyanate, contains toluene diisocyanate and Ethyl Acetate |
| D.O.T. HAZARD CLASS.....: | Flammable Liquid |
| UN/NA NO.....: | UN 1993 |
| PRODUCT REPORTABLE QTY....: | 19,000 lbs. |
| D.O.T. LABELS REQUIRED....: | Flammable Liquid |
| D.O.T. PLACARDS.....: | Flammable |
| FRT. CLASS BULK.....: | Isocyanate |
| FRT. CLASS PKG.....: | Chemicals NOI (Isocyanate) (NMFC 60000) |
| PRODUCT LABEL.....: | Mondur CB-75 |

## XII. ANIMAL TOXICITY DATA

ANIMAL TOXICITY - 100% solids polyisocyanate resin.

ORAL, LD50
(INGESTION).....: Greater than 25 g/kg (Rat)

DERMAL, LD50
(SKIN CONTACT).....: Greater than 6.5 g/kg (Rabbit)

EYE EFFECTS.....: Mechanical irritation observed (Rabbit)

SKIN EFFECTS.....: Non-irritating (Rabbit)

ANIMAL TOXICITY - Ethyl Acetate

ORAL, LD50.....: 5.6 g/kg (Rat)

INHALATION, LC50.....: Greater than 8000 ppm (Rat) - 8000 ppm caused no deaths; 16,000 ppm killed all test animals.

DERMAL.....: Greater than 18 g/kg (Rabbit)

OTHER.....: Guinea pigs exposed to 2000 ppm for 4 hr/day, 6 days/week for 65 exposures showed no ill effects.

ANIMAL TOXICITY - TDI

SENSITIZATION.....: Skin sensitizer in guinea pigs. One study (available upon request) with guinea pigs reported that repeated skin contact with TDI caused respiratory sensitization.

SUB-ACUTE/SUB-CHRONIC.....: Animal tests indicated that TDI inhalation caused irritation of the mucous membranes of the respiratory tract.

## XII. ANIMAL TOXICITY DATA (Continued)

CHRONIC.....: In lifetime inhalation studies conducted by Hazelton Labs for the International Isocyanate Institute, TDI did not demonstrate carcinogenic (cancer causing) activity in rats or mice. In this study, exposure to 0.05 to 0.15 ppm resulted in irritation of the mucous membranes of the respiratory tract.

The National Toxicology Program (NTP) reported that TDI administered by gavage caused an increase in tumors in exposed animals. Based on this study TDI has been listed by NTP and IARC.

MUTAGENIC TESTS.....: Results of mutagenic (genotoxic) studies are conflicting with some tests positive and others negative.

## XIII. APPROVALS

REASON FOR ISSUE.....: Revision
APPROVED BY.....: Paul D. Ziegler
TITLE.....: Manager, Product Safety

# ROWE PAINT MANUFACTURING CO.

TECHNICAL PRODUCT DATA BULLETIN

## DOD-P-15328 D
## PRIMER (WASH), PRETREATMENT
## FORMULA 117 FOR METALS

DOD-P-15328D is a two component pretreatment primer for ferrous and non-ferrous metals intended to promote adhesion and durability of the coating system. This primer is not an anticorrosive primer and should not be used by itself. The solvent and vehicle composition of this product makes usage acceptable in areas which air pollution regulations apply.

### PRODUCT DATA

| | |
|---|---|
| Product Code | M-2117 |
| Type of Material | Vinyl Butyral |
| Finish | Matte |
| Color | Translucent Green |
| Flash Point | 55°F minimum |
| Shelf Life | 1 year prior to mixing |
| No. of Components | Two |
| Mixing Ratio (supplied in proper ratio) | 4 parts base to 1 part acid |
| Pot Life | 8 hours |
| Dry to Touch | 15 minutes |
| Dry to Recoat | 30 minutes |
| Solids by Weight, Base | 18.5 - 21.0% |
| Solids by Volume, Mixed | 9.9% |
| Theoretical Coverage at 1 mil DFT | 159 sq. ft. per gallon |
| Optimum Film Thickness | 0.3 - 0.5 mils DFT |
| Theoretical Cover at 0.5 mil DFT | 318 sq. ft. per gallon |
| Viscosity | 63 - 75 KU |
| Weight per Gallon, Base | 7.3 - 7.7 pounds ave 7.5 lbs |
| Thinner and Clean-Up | T-8 Alcohol mixture |

CAUTION: This material is for Industrial use only. Rowe Paint Manufacturing Company will furnish Material Safety Data Sheets on all purchases and it is the responsibility of the applicator to be aware of the information therein contained.

MIXING: DOD-P-15328D is a two component product and must be mixed in proper proportions to be effective. Base component should be completely mixed prior to addition of acid component. Then acid component should be added to the base resin component slowly while continuing to stir. Mix only the amount of material to be used within 8 hours. Discard material not used during this period. DOD-P-15328D is supplied only in kits containing the proper ratios of each component. Four parts of base resin component are always mixed with one part acid component. Do not use acid component as a thinner.

APPLICATION: DOD-P-15328D may be applied preferably by spray, but small areas can be brush applied. A full wet coat should be spray applied, avoiding dust or dry spray. Thinner may be added or air pressure decrease to prevent dry spray. This product is translucent and is not intended to hide the substrate. Do not exceed 0.5 mil dry film thickness. Roll application and large area brush application are not recommended due to the need to control dry film thickness. Conventional spray equipment such as DeVilbiss MBC-510 gun, with "E" fluid tip and needle and #704, #765, or #78 air caps are acceptable.

SURFACE PREPARATION: The degree of surface preparation depends upon the finished system requirements, however as a general rule, blasted metal surfaces are recommended.



WARRANTY
The information contained herein is based upon the best information available at time of printing and data provided are intended for those having skill and ability to use products as recommended. Rowe Paint Manufacturing assumes no warranties, either implied or expressed, as to the purchase or application of these products, with the sole exception that if the Seller delivers off-standard materials, the Seller will, at its option, either replace the material or refund the full purchase price.

# ROWE PAINT MANUFACTURING CO.

TECHNICAL PRODUCT DATA BULLETIN

## N-2636 POLYURETHANE PRIMER

N-2636 Polyurethane Primer is intended for use a part of an organic coating system for interior surfaces of fuel storage tanks. This primer should be applied over a previously coated surface of wash primer conforming to DOD-P-15328D. N-2636 should be applied to obtain a dry film thickness of 2.0 mils or a total of 2.3 to 2.5 mils including the original coat of wash primer. N-2636 Polyurethane Primer is recommended to be applied within 8 hours after application of wash primer. A period of not less than 8 hours nor more than 48 hours should be allowed before application of the succeeding coat.

After application of N-2636 Primer, an approved Polyurethane intermediate coat and Polyurethane top coat should be applied to a total dry film thickness of not less than 6.0 mils.

### PRODUCT DATA

| | |
|---|---|
| Type | Catalyzed Polyurethane |
| Color | Yellow |
| Viscosity | 63 - 69 KU |
| Solids by Weight | 67.8 - 71.8% |
| Pigment by Weight | 39.7 - 43.0% |
| Weight per Gallon | 11.8 - 12.2 pounds |
| Flash Point | 30°F minimum |
| Mixing Ratio | 4 parts A to 1 part B |
| Shelf Life | 1 year prior to mixing |
| Pot Life @ 77°F | 4 hours |
| Solids by Volume | 51.3% |
| Theoretical Coverage ( at 2 mils DFT ) | 411 sq. ft. per gallon |
| Thinner and Clean Up | T-34 |
| Dry to Recoat | 8 hours |
| No. of Components | Two |

THIS MATERIAL COMPLIES WITH DEPARTMENT OF NAVY SPECIFICATION FOR INTERIOR COATING SYSTEMS FOR PETROLEUM FUEL STORAGE

CAUTION: This material is for Industrial use only. Rowe Paint Manufacturing Company will furnish Material Safety Data Sheets on all purchases and it is the responsibility of the applicator to be aware of the information therein contained.

SURFACE PREPARATION: Steel surfaces must be blasted to white metal in accordance with SSPC-SP-5. The area of blasted surface should be limited to allow initial pretreatment coating application during the same work shift. No longer than 8 hours should elapse prior to applying the wash primer.

All items in the coating system are two-component and must be properly mixed prior to use. Spray application is recommended except for brushed areas of N-2636 Primer over welds. The recommended tip size for application is .013 - .019.

SEQUENCE OF APPLICATION:

1. SP-5 White Metal Blast
2. DOD-P-15328D Wash Primer 0.3 - 0.5 mils
   ( Within 8 hours )
3. Brush apply two coats N-2636 Primer over welds
   Apply ½ to 8 hours after application of DOD-P-15328D
4. N-2636 Polyurethane Primer 2.0 mils
   Apply ½ to 8 hours after application of DOD-P-15328D
5. N-3633 Polyurethane Intermediate Coat 2.0 mils
   Apply 8 to 48 hours after primer
6. N-3634 Polyurethane Topcoat 2.0 mils
   Apply 8 to 48 hours after Intermediate Coat

Total minimum dry film thickness 6.0 mils

For areas with less than 6.0 mils total, apply an additional coat of N-3634 Polyurethane Topcoat.



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# ROWE PAINT MANUFACTURING CO.

TECHNICAL PRODUCT DATA BULLETIN

## N-3633 POLYURETHANE INTERMEDIATE COAT

N-3633 Polyurethane Intermediate Coat is intended for use as an intermediate coating in a high performance organic coating system specially developed to be used on interior surfaces of fuel storage tanks. N-3633 should be applied over a coat of N-2636 Polyurethane Primer during a period of 8 to48 hours after application of the prime coat. An approximate dry film thickness of 2.0 mils should be obtained using spray application.

A finish coat of N-3634 must be applied within 8 to 48 hours after application of the intermediate coat. To ensure proper performance of this coating system, it is essential that all coatings be applied in proper sequence and time intervals.

### PRODUCT DATA

| | |
|---|---|
| Type | Catalyzed Polyurethane |
| Color | Light Green |
| Viscosity | 58 - 64 KU |
| Solids by Weight | 64.5 - 68.5% |
| Pigment by Weight | 30.4 - 34.4% |
| Weight per Gallon | 11.4 - 11.8 pounds |
| Flash Point | 30°F minimum |
| Mixing Ratio ( Supplied in Proper Ratio ) | 3 parts A to 2 parts B |
| Shelf Life | 1 year prior to mixing |
| Pot Life @ 77°F | 4 hours |
| Solids by Volume | 49.2% |
| Theoretical Coverage ( at 2 mils DFT ) | 395 sq. ft. per gallon |
| Thinner and Clean Up | T-34 |
| Dry to Recoat | 8 hours minimum/48 hours maximum |
| No. of Components | Two |

THIS MATERIAL COMPLIES WITH DEPARTMENT OF NAVY SPECIFICATION FOR INTERIOR COATING SYSTEMS FOR PETROLEUM FUEL STORAGE

CAUTION: This material is for Industrial use only. Rowe Paint Manufacturing Company will furnish Material Safety Data Sheets on all purchases and it is the responsibility of the applicator to be aware of the information therein contained.

SURFACE PREPARATION: Steel surfaces must be blasted to white metal in accordance with SSPC-SP-5. The area of blasted surface should be limited to allow initial pretreatment coating application during the same work shift. No longer than 8 hours should elapse prior to applying the wash primer.

All items in the coating system are two-component and must be properly mixed prior to use. Spray application is recommended except for brushed areas of N-2636 Primer over welds. The recommended tip size for application is .013 - .019.

SEQUENCE OF APPLICATION:

1. SP-5 White Metal Blast
2. DOD-P-15328D Wash Primer 0.3 - 0.5 mils
   ( Within 8 hours )
3. Brush apply two coats N-2636 Primer over welds
   Apply ½ to 8 hours after application of DOD-P-15328D
4. N-2636 Polyurethane Primer 2.0 mils
   Apply ½ to 8 hours after application of DOD-P-15328D
5. N-3633 Polyurethane Intermediate Coat 2.0 mils
   Apply 8 to 48 hours after primer
6. N-3634 Polyurethane Topcoat 2.0 mils
   Apply 8 to 48 hours after Intermediate Coat

Total minimum dry film thickness 6.0 mils

For areas with less than 6.0 mils total, apply an additional coat of N-3634 Polyurethane Topcoat.



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# ROWE PAINT MANUFACTURING CO.

TECHNICAL PRODUCT DATA BULLETIN

## N-3634 POLYURETHANE TOPCOAT

N-3634 Polyurethane Topcoat is intended for use as a finish coat of an organic coating system for use on interior surfaces of fuel storage tanks. This finish coat should be spray applied at approximately 2.0 mils dry film thickness, however a total of 6.0 mils minimum is essential and an additional coat of N-3634 may be applied to achieve necessary overall film thickness.

N-3634 must be applied within 8 to 48 hours after application of the intermediate coat. To ensure proper performance ot this coating system, it is essential that all coatings be applied in proper sequence and time intervals.

### PRODUCT DATA

| | |
|---|---|
| Type | Catalyzed Polyurethane |
| Color | White |
| Viscosity | 58 - 64 KU |
| Solids by Weight | 62.7 - 66.7% |
| Pigment by Weight | 21.5 - 25.5% |
| Weight per Gallon | 10.4 - 10.8 pounds |
| Flash Point | 30°F minimum |
| Mixing Ratio ( Supplied in Proper Ratio ) | 3 parts A to 2 parts B |
| Shelf Life | 1 year prior to mixing |
| Pot Life @ 77°F | 4 hours |
| Solids by Volume | 50.8% |
| Theoretical Coverage ( at 2 mils DFT ) | 407 sq. ft. per gallon |
| Thinner and Clean Up | T-34 |
| Dry to Recoat | No topcoat necessary |
| No. of Components | Two |

THIS MATERIAL COMPLIES WITH DEPARTMENT OF NAVY SPECIFICATION FOR INTERIOR COATING SYSTEMS FOR PETROLEUM FUEL STORAGE

CAUTION: This material is for Industrial use only. Rowe Paint Manufacturing Company will furnish Material Safety Data Sheets on all purchases and it is the responsibility of the applicator to be aware of the information therein contained.

SURFACE PREPARATION: Steel surfaces must be blasted to white metal in accordance with SSPC-SP-5. The area of blasted surface should be limited to allow initial pretreatment coating application during the same work shift. No longer than 8 hours should elapse prior to applying the wash primer.

All items in the coating system are two-component and must be properly mixed prior to use. Spray application is recommended except for brushed areas of N-2636 Primer over welds. The recommended tip size for application is .013 - .019.

SEQUENCE OF APPLICATION:

1. SP-5 White Metal Blast
2. DOD-P-15328D Wash Primer 0.3 - 0.5 mils
   ( Within 8 hours )
3. Brush apply two coats N-2636 Primer over welds
   Apply ½ to 8 hours after application of DOD-P-15328D
4. N-2636 Polyurethane Primer 2.0 mils
   Apply ½ to 8 hours after application of DOD-P-15328D
5. N-3633 Polyurethane Intermediate Coat 2.0 mils
   Apply 8 to 48 hours after primer
6. N-3634 Polyurethane Topcoat 2.0 mils
   Apply 8 to 48 hours after Intermediate Coat

Total minimum dry film thickness 6.0 mils

For areas with less than 6.0 mils total, apply an additional coat of N-3634 Polyurethane Topcoat.



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# APPENDIX D

# SOURCE CALCULATIONS

# APPENDIX D

## SOURCE CALCULATIONS

Wash Primer (per Slice)

Mass of volatile hydrocarbons in each slice:

$$m_{voc} = (5 \text{ gallons}) (1 \text{ m}^3/264.3 \text{ gallons}) (960 \text{ kg/m}^3) (0.88)$$

$$= 15.98 \text{ kg}$$

Overspray (2 % ) = 0.3196 kg

85.5 % hydrocarbon vapors emitted during spraying
14.5 % hydrocarbon vapors emitted during drying

Rate of generation during spraying:

$$g_s (1.5) = (0.855) (15.98 - 0.3196) + 0.3196$$

$$g_s = 9.1395 \text{ kg/hr}$$

Rate of generation during drying:

$$g_d = (0.145) (15.98 - 0.3196) = a (0.5 )/2$$

$$a = 9.083 \text{ kg/hr}$$

$$g_d = 9.083 - 18.1666 \text{ t } [\text{kg/hr}]$$

Polyurethane Primer (per Slice)

Mass of component A used in each slice:

$$m_A = (4 \text{ gallons}) (1 \text{ m}^3/264.3 \text{ gallons}) (1470 \text{ kg/m}^3)$$

$$= 22.2472 \text{ kg}$$

Mass of volatile hydrocarbons in A in each slice:

$$m_{voc,A} = (0.487) (22.2474 \text{ kg}) = 10.8344 \text{ kg}$$

Mass of component B used in each slice:

$$m_B = (1 \text{ gallon}) (1 \text{ m}^3/264.3 \text{ gallon}) (1190 \text{ kg/m}^3) = 4.5025 \text{ kg}$$

Mass of volatile hydrocarbons in B in each slice:

$$m_{voc,B} = (0.34) (4.5025 \text{ kg}) = 1.5308 \text{ kg}$$

Total mass of volatile hydrocarbons in each slice:

$$m_{voc,t} = 10.8344 + 1.5308 = 12.3652 \text{ kg}$$

Overspray (2 %) = 0.2473 kg

54 % hydrocarbon vapors emitted during spraying
46 % hydrocarbon vapors emitted during drying

Rate of generation during spraying:

$g_S$ (1.5) = (0.54) (12.3652 - 0.2473) + 0.2473 = 6.7910

$g_S$ = 4.5273 kg/hr

Rate of generation during drying:

[ (a) (2.5) ] / 2 = (0.46) (12.3652 - 0.2473) = 5.5742

a = 4.4594 kg/hr

$g_d$ = 4.4594 - 1.7838 t [kg/hr]

Intermediate Coat (per Slice)

Mass of component A used in each slice:

$$m_A = (3 \text{ gallons}) (1 \text{ m}^3/264.3 \text{ gallons}) (1570 \text{ kg/m}^3)$$

$$= 17.8206 \text{ kg}$$

Mass of volatile hydrocarbons in A in each slice:

$$m_{voc,A} = (0.488) ( 17.8206 \text{ kg}) = 8.6965 \text{ kg}$$

Mass of component B used in each slice:

$$m_B = (2 \text{ gallon}) (1 \text{ m}^3/264.3 \text{ gallon}) (1080 \text{ kg/m}^3) = 8.1725 \text{ kg}$$

Mass of volatile hydrocarbons in B in each slice:

$$m_{voc,B} = (0.505) (8.1725 \text{ kg}) = 4.1271 \text{ kg}$$

Total mass of volatile hydrocarbons in each slice:

$$m_{voc,t} = 8.6965 + 4.1271 = 12.8236 \text{ kg}$$

Overspray (2 %) = 0.2565 kg

29 % hydrocarbon vapors emitted during spraying
71 % hydrocarbon vapors emitted during drying

Rate of generation during spraying:

$g_s$ (1.5) = (0.29) (12.8236 - 0.2565) + 0.2565 = 3.9010

$g_s$ = 2.6006 kg/hr

Rate of generation during drying:

[ (a) (7) ] / 2 = (0.71) (12.8236 - 0.2565) = 8.9226

a = 2.5493 kg/hr

$g_d$ = 2.5493 - 0.3642 t [kg/hr]

Top Coat (per Slice)

Mass of component A used in each slice:

$$m_A = (3 \text{ gallons}) (1 \text{ m}^3/264.3 \text{ gallons}) (1360 \text{ kg/m}^3)$$

$$= 15.437 \text{ kg}$$

Mass of volatile hydrocarbons in A in each slice:

$$m_{voc,A} = (0.51) (15.437 \text{ kg}) = 7.8729 \text{ kg}$$

Mass of component B used in each slice:

$$m_B = (2 \text{ gallon}) (1 \text{ m}^3/264.3 \text{ gallon}) (1100 \text{ kg/m}^3) = 8.3239 \text{ kg}$$

Mass of volatile hydrocarbons in B in each slice:

$$m_{voc,B} = (0.424) (8.3239 \text{ kg}) = 3.5293 \text{ kg}$$

Total mass of volatile hydrocarbons in each slice:

$$m_{voc,t} = 7.8729 + 3.5293 = 11.4022 \text{ kg}$$

Overspray (2 %) = 0.2280 kg

36.5 % hydrocarbon vapors emitted during spraying
63.5 % hydrocarbon vapors emitted during drying

Rate of generation during spraying:

$g_S$ (1.5) = (0.365) (11.4022 - 0.2280) + 0.2280 = 4.3066

$g_S$ = 2.8711 kg/hr

Rate of generation during drying:

[ (a) (5) ] / 2 = (0.635) ( 11.4022 - 0.2280) = 7.0956

a = 2.8382 kg/hr

$g_d$ = 2.8382 - 0.5676 t [kg/hr]

Wash Primer (in Floating Pan)

Mass of volatile hydrocarbons:

$m_{voc}$ = (5 gallons/114.66 $m^3$) (216.315 $m^3$ ) (1 $m^3$/264.3 gallons)
(960 kg/$m^3$) (0.88)

= 30.1510 kg

Overspray (2 % ) = 0.6030 kg

92.2 % hydrocarbon vapors emitted during spraying
7.8 % hydrocarbon vapors emitted during drying

Rate of generation during spraying:

$g_S$ (3) = (0.922) (30.1510 - 0.6030) + 0.6030

$g_S$ = 9.2821 kg/hr

Rate of generation during drying:

$g_d$ = (0.078 ) ( 30.1510 - 0.6030 ) = a (0.5 )/2

a = 9.22

$g_d$ = 9.22 - 18.4380 t [kg/hr]

Polyurethane Primer (in Floating Pan)

Mass of component A

$m_A$ = (4/5) (9.4329 gallons) (1 $m^3$/264.3 gallons) (1470 $kg/m^3$)

= 41.9716 kg

Mass of volatile hydrocarbons in A:

$m_{voc,A}$ = (0.487) (41.9716 kg) = 20.4402 kg

Mass of component B:

$m_B$ = (1/5) (9.4329 gallon) (1 $m^3$/264.3 gallon) (1190 $kg/m^3$)

= 8.4942 kg

Mass of volatile hydrocarbons in B:

$m_{voc,B}$ = (0.34) (8.4942 kg) = 2.8880 kg

Total mass of volatile hydrocarbons:

$m_{voc,t}$ = 20.4402 + 2.8880 = 23.3282 kg

Overspray (2 %) = 0.4666 kg

70 % hydrocarbon vapors emitted during spraying
30 % hydrocarbon vapors emitted during drying

Rate of generation during spraying:

$g_S$ (3) = (0.70) (23.3282 - 0.4666) + 0.4666 = 16.4697

$g_S$ = 5.4899 kg/hr

Rate of generation during drying:

[ (a) (2.5) ] / 2 = (0.30) ( 23.3282 - 0.4666 ) = 6.8585

a = 5.4868

$g_d$ = 5.4868 - 2.1947 t [kg/hr]

Intermediate Coat (in Floating Pan)

Mass of component A:

$m_A$ = ( 3/5) (18.866 gallons) (1 $m^3$/264.3 gallons) (1570 $kg/m^3$)

= 67.2409 kg

Mass of volatile hydrocarbons in A:

$m_{voc,A}$ = (0.488) (67.2409 kg) = 32.8136 kg

Mass of component B:

$m_B$ = (2/5) (18.866 gallons) (1 $m^3$/264.3 gallon) (1080 $kg/m^3$)

= 30.8366 kg

Mass of volatile hydrocarbons in B:

$m_{voc,B}$ = (0.505) (30.8366 kg) = 15.5725 kg

Total mass of volatile hydrocarbons:

$m_{voc,t}$ = 32.8136 + 15.5725 = 48.3861 kg

Overspray (2 %) = 0.9677 kg

63 % hydrocarbon vapors emitted during spraying
37 % hydrocarbon vapors emitted during drying

Rate of generation during spraying:

$g_S$ (6) = (0.63) (48.3861 - 0.9667) + 0.9667 = 30.8419

$g_S$ = 5.1403 kg/hr

Rate of generation during drying:

[ (a) (7) ] / 2 = (0.37) (48.3861 - 0.9667) = 17.5452

a = 5.0129

$g_d$ = 5.0129 - 0.7161 t [kg/hr]

Top Coat (in Floating Pan)

Mass of component A:

$m_A$ = (3/5) (18.866 gallons) (1 $m^3$/264.3 gallons) (1360 $kg/m^3$)

= 58.2469 kg

Mass of volatile hydrocarbons in A:

$m_{voc,A}$ = (0.51) (58.2469 kg) = 29.7059 kg

Mass of component B:

$m_B$ = (2/5) (18.866 gallons) (1 $m^3$/264.3 gallon) (1100 $kg/m^3$)

= 31.4076 kg

Mass of volatile hydrocarbons in B:

$m_{voc,B}$ = (0.424) (31.4076 kg) = 13.3168 kg

Total mass of volatile hydrocarbons in each slice:

$m_{voc,t}$ = 29.7059 + 13.3168 = 43.0227 kg

Overspray (2 %) = 0.8605 kg

70 % hydrocarbon vapors emitted during spraying
30 % hydrocarbon vapors emitted during drying

Rate of generation during spraying:

$g_S$ (6) = (0.70) (43.0227 - 0.8605) + 0.8605 = 30.37404

$g_S$ = 5.0623 kg/hr

Rate of generation during drying:

[ (a) (5) ] / 2 = (0.3) ( 43.0227 - 0.8605 ) = 12.6487

a = 5.0595

$g_d$ = 5.0595 - 1.0119 t [kg/hr]

# APPENDIX E

# COMPLETE WORK SCHEDULE

# COMPLETE WORK SCHEDULE

SLICE

| SHIFT | TEAM | Time (hr) | A | B | D | E | H | J | K | L | M | P | PAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | | | | | | | | | | | |
| | | 1 | | | | | | | | | | | |
| | | 2 | BLAST A | | | | | | | | | | |
| | | 3 | | | | | | | | | | | |
| | | 4 | | | | | | | | | | | |
| 1 | 1 | 5 | | | | | | | | | | | |
| | | 6 | CLEAN | | | | | | | | | | |
| | | 7 | | | | | | | | | | | |
| | | 8 | WASH PRIME | | | | | | | | | | |
| | | 9 | CLEAN | | | | | | | | | | |
| | | 10 | PRIME A | | | | | | | | | | |
| | | 11 | | | | | | | | | | | |
| | | 12 | | | | | | | | | | | |
| | | 13 | | BLAST B | | | | | | | | | |
| | | 14 | | | | | | | | | | | |
| 2 | 2 | 15 | | | | | | | | | | | |
| | | 16 | | CLEAN | | | | | | | | | |
| | | 17 | | | | | | | | | | | |
| | | 18 | | WASH PRIME | | | | | | | | | |
| | | 19 | | CLEAN | | | | | | | | | |
| | | 20 | | PRIME B | | | | | | | | | |
| | | 21 | | | | | | | | | | | |
| | | 22 | | | | | | | | | | | |
| | | 23 | | | | | | | | | | | |
| | | 24 | | | | | | | | | | | |
| | | 25 | | | | | | | | | | | |
| | | 26 | | | | | | | | | | | |
| | | 27 | | | BLAST D | | | | | | | | |
| | | 28 | | | | | | | | | | | |
| 3 | 1 | 29 | | | | | | | | | | | |
| | | 30 | | | CLEAN | | | | | | | | |
| | | 31 | | | | | | | | | | | |
| | | 32 | | | WASH PRIME | | | | | | | | |
| | | 33 | | | | | | | | | | | |
| | | 34 | | | PRIME D | | | | | | | | |
| | | 35 | | | | | | | | | | | |
| | | 36 | | | | | | | | | | | |
| | | 37 | | | | BLAST E | | | | | | | |
| | | 38 | | | | | | | | | | | |
| | | 39 | | | | | | | | | | | |
| 4 | 2 | 40 | | | | CLEAN | | | | | | | |
| | | 41 | | | | | | | | | | | |
| | | 42 | | | | WASH PRIME | | | | | | | |
| | | 43 | | | | CLEAN | | | | | | | |
| | | 44 | | | | PRIME E | | | | | | | |

# COMPLETE WORK SCHEDULE (CONTINUED)

| SHIFT | TEAM | Time (hr) | A | B | D | E | H | J | K | L | M | P | PAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 45 | INT A | | | | | | | | | | |
| | | 46 | | INT B | | | | | | | | | |
| | | 47 | | | | | | | | | | | |
| | | 48 | | | | | | | | | | | |
| | | 49 | | | | | | | | | | | |
| | | 50 | | | | | | | | | | | |
| | | 51 | | | | | BLAST H | | | | | | |
| | | 52 | | | | | | | | | | | |
| 5 | 1 | 53 | | | | | | | | | | | |
| | | 54 | | | | | CLEAN | | | | | | |
| | | 55 | | | | | | | | | | | |
| | | 56 | | | | | WASH PRIME | | | | | | |
| | | 57 | | | | | CLEAN | | | | | | |
| | | 58 | | | | | PRIME H | | | | | | |
| | | 59 | 1ST TOP A | | | | | | | | | | |
| | | 60 | | 1ST TOP B | | | | | | | | | |
| 6 | 2 | 61 | | | | | | | | | | | |
| | | 62 | | | INT D | | | | | | | | |
| | | 63 | | | | INT E | | | | | | | |
| | | 64 | | | | | | | | | | | |
| | | 65 | | | | | | | | | | | |
| | | 66 | | | | | | | | | | | |
| | | 67 | | | | | | | | | | | |
| | | 68 | | | | | | | | | | | |
| | | 69 | | | | | | | | | | | |
| | | 70 | | | | | | | | | | | |
| | | 71 | | | | | | | | | | | |
| | | 72 | | | | | | | | | | | |
| | | 73 | | | | | | | | | | | |
| | | 74 | | | | | | | | | | | |
| | | 75 | | | | | | BLAST J | | | | | |
| | | 76 | | | | | | | | | | | |
| 7 | 1 | 77 | | | | | | | | | | | |
| | | 78 | | | | | | CLEAN | | | | | |
| | | 79 | | | | | | | | | | | |
| | | 80 | | | | | | WASH PRIME | | | | | |
| | | 81 | | | | | | CLEAN | | | | | |
| | | 82 | | | | | | PRIME J | | | | | |
| | | 83 | 2ND TOP A | | | | | | | | | | |
| | | 84 | | 2ND TOP B | | | | | | | | | |
| | | 85 | | | | | | | | | | | |
| 8 | 2 | 86 | | | 1ST TOP D | | | | | | | | |
| | | 87 | | | | 1ST TOP E | | | | | | | |
| | | 88 | | | | | | | | | | | |
| | | 89 | | | | | INT H | | | | | | |

# COMPLETE WORK SCHEDULE (CONTINUED)

| SHIFT | TEAM | Time (hr) | A | B | D | E | H | J | K | L | M | P | PAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 90 | | | | | | | | | | | |
| | | 91 | | | | | | | | | | | |
| | | 92 | | | | | | | | | | | |
| | | 93 | | | | | | | | | | | |
| | | 94 | | | | | | | | | | | |
| | | 95 | | | | | | | | | | | |
| | | 96 | | | | | | | | | | | |
| | | 97 | | | | | | | | | | | |
| | | 98 | | | | | | | | | | | |
| | | 99 | | | | | | | BLAST K | | | | |
| | | 100 | | | | | | | | | | | |
| 9 | 1 | 101 | | | | | | | | | | | |
| | | 102 | | | | | | | CLEAN | | | | |
| | | 103 | | | | | | | | | | | |
| | | 104 | | | | | | | WASH PRIME | | | | |
| | | 105 | | | | | | | CLEAN | | | | |
| | | 106 | | | | | | | PRIME K | | | | |
| | | 107 | | | 2ND TOP D | | | | | | | | |
| | | 108 | | | | 2ND TOP E | | | | | | | |
| 10 | 2 | 109 | | | | | | | | | | | |
| | | 110 | | | | | 1ST TOP H | | | | | | |
| | | 111 | | | | | | INT J | | | | | |
| | | 112 | | | | | | | | | | | |
| | | 113 | | | | | | | | | | | |
| | | 114 | | | | | | | | | | | |
| | | 115 | | | | | | | | | | | |
| | | 116 | | | | | | | | | | | |
| | | 117 | | | | | | | | | | | |
| | | 118 | | | | | | | | | | | |
| | | 119 | | | | | | | | | | | |
| | | 120 | | | | | | | | | | | |
| | | 121 | | | | | | | | | | | |
| | | 122 | | | | | | | | | | | |
| | | 123 | | | | | | | | BLAST L | | | |
| | | 124 | | | | | | | | | | | |
| 11 | 1 | 125 | | | | | | | | | | | |
| | | 126 | | | | | | | | CLEAN | | | |
| | | 127 | | | | | | | | | | | |
| | | 128 | | | | | | | | WASH PRIME | | | |
| | | 129 | | | | | | | | CLEAN | | | |
| | | 130 | | | | | | | | PRIME L | | | |
| | | 131 | | | | | 2ND TOP H | | | | | | |
| | | 132 | | | | | | | | | | | |
| 12 | 2 | 133 | | | | | | 1ST TOP J | | | | | |
| | | 134 | | | | | | | INT K | | | | |

# COMPLETE WORK SCHEDULE (CONTINUED)

| SHIFT | TEAM | Time (hr) | A | B | D | E | H | J | K | L | M | P | PAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 135 | | | | | | | | | | | |
| | | 136 | | | | | | | | | | | |
| | | 137 | | | | | | | | | | | |
| | | 138 | | | | | | | | | | | |
| | | 139 | | | | | | | | | | | |
| | | 140 | | | | | | | | | | | |
| | | 141 | | | | | | | | | | | |
| | | 142 | | | | | | | | | | | |
| | | 143 | | | | | | | | | | | |
| | | 144 | | | | | | | | | | | |
| | | 145 | | | | | | | | | | | |
| | | 146 | | | | | | | | | | | |
| | | 147 | | | | | | | | | BLAST M | | |
| | | 148 | | | | | | | | | | | |
| 13 | 1 | 149 | | | | | | | | | | | |
| | | 150 | | | | | | | | | CLEAN | | |
| | | 151 | | | | | | | | | | | |
| | | 152 | | | | | | | | | WASH PRIME | | |
| | | 153 | | | | | | | | | CLEAN | | |
| | | 154 | | | | | | | | | PRIME M | | |
| | | 155 | | | | | | | | | | | |
| | | 156 | | | | | | | | | | | |
| | | 157 | | | | | | | | | | BLAST P | |
| | | 158 | | | | | | | | | | | |
| | | 159 | | | | | | | | | | | |
| 14 | 2 | 160 | | | | | | | | | | CLEAN | |
| | | 161 | | | | | | | | | | | |
| | | 162 | | | | | | | | | | WASH PRIME | |
| | | 163 | | | | | | | | | | CLEAN | |
| | | 164 | | | | | | | | | | PRIME P | |
| | | 165 | | | | | | | 1ST TOP K | | | | |
| | | 166 | | | | | | | | INT L | | | |
| | | 167 | | | | | | | | | | | |
| | | 168 | | | | | | | | | | | |
| | | 169 | | | | | | | | | | | |
| | | 170 | | | | | | | | | | | |
| | | 171 | | | | | | 2ND TOP J | | | | | |
| | | 172 | | | | | | | | | INT M | | |
| | | 173 | | | | | | | | | | | |
| 15 | 1 | 174 | | | | | | | | | | INT P | |
| | | 175 | | | | | | | 2ND TOP K | | | | |
| | | 176 | | | | | | | | | | | |
| | | 177 | | | | | | | | 1ST TOP L | | | |
| | | 178 | | | | | | | | | | | |
| | | 179 | | | | | | | | | | | |
| | | 180 | | | | | | | | | | | |
| | | 181 | | | | | | | | | | | |
| | | 182 | | | | | | | | | | | |

# COMPLETE WORK SCHEDULE (CONTINUED)

| SHIFT | TEAM | Time (hr | A | B | D | E | H | J | K | L | M | P | PAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 183 | | | | | | | | | | | |
| | | 184 | | | | | | | | | | | |
| | | 185 | | | | | | | | | | | |
| | | 186 | | | | | | | | | | | |
| | | 187 | | | | | | | | | | | |
| | | 188 | | | | | | | | | | | |
| | | 189 | | | | | | | | | | | |
| | | 190 | | | | | | | | | | | |
| | | 191 | | | | | | | | | | | |
| | | 192 | | | | | | | | | | | |
| | | 193 | | | | | | | | 2ND TOP L | | | |
| 16 | 1 | 194 | | | | | | | | | 1ST TOP M | | |
| | | 195 | | | | | | | | | | | |
| | | 196 | | | | | | | | | | 1ST TOP P | |
| | | 197 | | | | | | | | | | | |
| | | 198 | | | | | | | | | | | |
| | | 199 | | | | | | | | | | | |
| | | 200 | | | | | | | | | | | |
| | | 201 | | | | | | | | | | | |
| | | 202 | | | | | | | | | | | |
| | | 203 | | | | | | | | | | | |
| | | 204 | | | | | | | | | | | |
| | | 205 | | | | | | | | | | | |
| | | 206 | | | | | | | | | | | |
| | | 207 | | | | | | | | | | | |
| | | 208 | | | | | | | | | | | |
| | | 209 | | | | | | | | | | | |
| | | 210 | | | | | | | | | | | |
| | | 211 | | | | | | | | | | | |
| | | 212 | | | | | | | | | | | |
| | | 213 | | | | | | | | | | | |
| | | 214 | | | | | | | | | | | |
| | | 215 | | | | | | | | | | | |
| | | 216 | | | | | | | | | | | |
| | | 217 | | | | | | | | | 2ND TOP M | | |
| 17 | 1 | 218 | | | | | | | | | | | |
| | | 219 | | | | | | | | | | 2ND TOP P | |
| | | 220 | | | | | | | | | | | |
| | | 221 | | | | | | | | | | | |
| | | 222 | | | | | | | | | | | |
| | | 223 | | | | | | | | | | | |
| | | 224 | | | | | | | | | | | |
| | | 225 | | | | | | | | | | | |
| | | 226 | | | | | | | | | | | |
| | | 227 | | | | | | | | | | | |
| | | 228 | | | | | | | | | | | |
| | | 229 | | | | | | | | | | | |
| | | 230 | | | | | | | | | | | |

# COMPLETE WORK SCHEDULE (CONTINUED)

| SHIFT | TEAM | Time (hr | A | B | D | E | H | J | L | M | P | PAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 231 | | | | | | | | | | |
| | | 232 | | | | | | | | | | |
| | | 233 | | | | | | | | | | |
| | | 234 | | | | | | | | | | |
| | | 235 | | | | | | | | | | |
| | | 236 | | | | | | | | | | |
| | | 237 | | | | | | | | | | |
| | | 238 | | | | | | | | | | |
| | | 239 | | | | | | | | | | |
| | | 240 | | | | | | | | | | |
| | | 241 | | | | | | | | | | |
| | | 242 | | | | | | | | | | |
| | | 243 | | | | | | | | | | |
| | | 244 | | | | | | | | | | |
| | | 245 | | | | | | | | | | BLAST 1ST HALF |
| 18 | 1 | 246 | | | | | | | | | | INCLUDING CLEAN-UP |
| | | 247 | | | | | | | | | | |
| | | 248 | | | | | | | | | | |
| | | 249 | | | | | | | | | | |
| | | 250 | | | | | | | | | | |
| | | 251 | | | | | | | | | | WASH PRIME 1ST HALF |
| | | 252 | | | | | | | | | | |
| | | 253 | | | | | | | | | | |
| 19 | 1 | 254 | | | | | | | | | | CLEAN |
| | | 255 | | | | | | | | | | PRIME 1ST HALF |
| | | 256 | | | | | | | | | | |
| | | 257 | | | | | | | | | | |
| | | 258 | | | | | | | | | | |
| | | 259 | | | | | | | | | | |
| | | 260 | | | | | | | | | | |
| | | 261 | | | | | | | | | | |
| | | 262 | | | | | | | | | | |
| | | 263 | | | | | | | | | | |
| | | 264 | | | | | | | | | | |
| | | 265 | | | | | | | | | | |
| | | 266 | | | | | | | | | | |
| | | 267 | | | | | | | | | | |
| | | 268 | | | | | | | | | | |
| | | 269 | | | | | | | | | | BLAST 2ND HALF |
| 20 | 1 | 270 | | | | | | | | | | INCLUDING CLEAN-UP |
| | | 271 | | | | | | | | | | |
| | | 272 | | | | | | | | | | |
| | | 273 | | | | | | | | | | |
| | | 274 | | | | | | | | | | |

# COMPLETE WORK SCHEDULE (CONTINUED)

| SHIFT | TEAM | Time (hr) | A | B | D | E | H | J | - | _ | M | P | PAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 275 | | | | | | | | | | | WASH PRIME 2ND HALF |
| | | 276 | | | | | | | | | | | |
| | | 277 | | | | | | | | | | | |
| 21 | 1 | 278 | | | | | | | | | | | CLEAN |
| | | 279 | | | | | | | | | | | PRIME 2ND HALF |
| | | 280 | | | | | | | | | | | |
| | | 281 | | | | | | | | | | | |
| | | 282 | | | | | | | | | | | |
| | | 283 | | | | | | | | | | | |
| | | 284 | | | | | | | | | | | |
| | | 285 | | | | | | | | | | | |
| | | 286 | | | | | | | | | | | |
| | | 287 | | | | | | | | | | | |
| | | 288 | | | | | | | | | | | |
| | | 289 | | | | | | | | | | | |
| | | 290 | | | | | | | | | | | INT PAN |
| 22 | 1 | 291 | | | | | | | | | | | |
| | | 292 | | | | | | | | | | | |
| | | 293 | | | | | | | | | | | |
| | | 294 | | | | | | | | | | | |
| | | 295 | | | | | | | | | | | |
| | | 296 | | | | | | | | | | | |
| | | 297 | | | | | | | | | | | |
| | | 298 | | | | | | | | | | | |
| | | 299 | | | | | | | | | | | |
| | | 300 | | | | | | | | | | | |
| | | 301 | | | | | | | | | | | |
| | | 302 | | | | | | | | | | | |
| | | 303 | | | | | | | | | | | |
| | | 304 | | | | | | | | | | | |
| | | 305 | | | | | | | | | | | |
| | | 306 | | | | | | | | | | | |
| | | 307 | | | | | | | | | | | |
| | | 308 | | | | | | | | | | | |
| | | 309 | | | | | | | | | | | |
| | | 310 | | | | | | | | | | | |
| | | 311 | | | | | | | | | | | |
| | | 312 | | | | | | | | | | | |
| | | 313 | | | | | | | | | | | |
| | | 314 | | | | | | | | | | | |
| 23 | 1 | 315 | | | | | | | | | | | TOP COAT |
| | | 316 | | | | | | | | | | | |
| | | 317 | | | | | | | | | | | |
| | | 318 | | | | | | | | | | | |

# APPENDIX F

# PROGRAM LISTING

```
REM  DATE:  12 MARCH 1990
REM  FILENAME IS CONCENTRATION (C=G/CUM)
REM  FILE WILL PREDICT THE CONTAMINANT CONCENTRATION IN A
      'BULK FUEL TANK
'
REM  PROGRAM USES THE FOURTH ORDER RUNGE-KUTTA METHOD TO SOLVE
     'SET OF SIMULTANEOUS DIFFERENTIAL EQUATIONS.  IT ALSO CALCULATES
      'CONCENTRATION AS A FUNCTION OF TIME AND SPACE FOR TIME
      'VARYING SOURCE IN A SEQUENTIAL BOX MODEL:C=C(X,Y,Z,T)
'
REM   PARAMETERS:
       'KNOWN:  Q=VOLUMETRIC FLOW RATE (CUM/HR),V=VOLUME (CUM),
       'C=CONCENTRATION  (G/CUM)
       'S=SOURCE STRENGTH (G/HR), Xi=% MASS FLOW INTO BOX i,
       'Yi=% MASS FLOW OUT OF BOX i, Ki=% VOL OF BOX i, Gi=% SOURCE IN
       'BOX i, T=TIME (HOURS), H=TIME STEP (HOUR), KAD= ADSORPTION
       'COEFFICIENT (M/HR), ASi=SURFACE AREA OF BOX i (SM)
      'SELECTED: Fij= EXCHANGE FACTOR.  NOTE:  EXCHANGE FACTOR INTO
      'BOX i,(Fji) DOES NOT NECESSARILY EQUAL EXCHANGE FACTOR OUT OF
       'BOX i, (Fij).  UNKNOWN:  THE CONCENTRATION IN EACH BOX AND
       'THE TOTAL CONCENTRATION AS A FUNCTION OF TIME.
       'SAT = TOTAL SOURCE IN SLICE A.  ST = TOTAL SOURCE IN PAN
      'TC = TOTAL CONCENTRATION MEN ARE SUBJECTED TO WHILE WORKING
DEFSNG c,A,B,f
OPEN "CLIP:" FOR OUTPUT AS #1
LET Q=22088: V=4219.7: t=0!: h=.01: KAD=0
Ka=.1: Kb=.1: Kd=.1: Ke=.1: Kh=.1: Kj=.1: Kk=.1: Kl=.1: Km=.1: Kp=.1
ASa=114.66:  ASb=114.66:  ASd=114.66:  ASe=114.66:  ASh=114.66
ASj=114.66:  ASk=114.66:  ASl=114.66:  ASm=114.66:  ASp=114.66
k1=.25: k2=.25: k3=.25: k4=.25:TC=0!
Co=0!: N=0!:SAT=0!:SBT=0!:SDT=0!:SET=0!:SHT=0!:SJT=0!:SKT=0!:SLT=0!:SMT=0!:SPT=0!:ST=0
!
REM EXCHANGE FACTORS CHANGE EACH TIME MEN MOVE INTO NEW SLICE
'PRINT ,"Concentration vs. Time "
'PRINT,"t (hours)","Total  Exposure"
'PRINT "t (hours)","Ca (g/cum)","Cb (g/cum)","Cd (g/cum)","Ce (g/cum)","Ch (g/cum)",
'PRINT "t (hours)","Cj (g/cum)","Ck (g/cum)","Cl (g/cum)","Cm (g/cum)","Cp (g/cum)"
10 WHILE t<= 336 ' approx 14 days
   SAT=SAT+Sa*h
   SBT=SBT+Sb*h
   SDT=SDT+Sd*h
   SET=SET+Sd*h
   SHT=SHT+Sh*h
    SJT=SJT+Sj*h
   SKT=SKT+Sk*h
```

```
    SLT=SLT+Sl*h
    SMT=SMT+Sm*h
    SPT=SPT+ Sp*h
    ST=ST+s1*h
20  IF t<=323 THEN
'   PAN DRYING
        s1=5059.5-1011.9*(t-318)
IF t<=318 THEN
'PAINT PAN (TOP)-MODIFY EXCHANGE FACTORS FOR NEW SLICES
TC=TC+C1*h
     f12=1!: f23=.38: f34=.38
     f21=.62: f32=0!: f43=0!
    x1=.38: x4=.62: y4=1!
    s1=5062.3
IF t<=312 THEN
'EMPTY
TC=TC
     f12=.38: f23=.38: f34=.38
     f21=0!: f32=0!: f43=0!
    x1=.38: x4=.62: y4=1!
   s1=0!
IF t<=301 THEN
       s1=5012.9-716.1*(t-294)
IF t<=294 THEN
'PAINT PAN (INTERMEDIATE)
TC=TC+C1*h
     f12=1!: f23=.38: f34=.38
     f21=.62: f32=0!: f43=0!
    x1=.38: x4=.62: y4=1!
    s1=5140.3
IF t<=288 THEN
'EMPTY
TC=TC
     f12=.38: f23=.38: f34=.38
     f21=0!: f32=0!: f43=0!
    x1=.38: x4=.62: y4=1!
   s1=0
IF t<=283 THEN
       s1=5486.8-2194.7*(t-280.5)
IF t<=280.5 THEN
'PAINT PAN (PRIME - 2ND HALF)
TC=TC+C1*h
     f12=1!: f23=.38: f34=.38
     f21=.62: f32=0!: f43=0!
    x1=.38: x4=.62: y4=1!
```

```
    s1=5489.9
IF t<=277.5 THEN
      s1=9220-18438!*(t-277!)
IF t<=277! THEN
'WASH PRIME PAN (2ND HALF)
     f12=1!: f23=.38: f34=.38
     f21=.62: f32=0!: f43=0!
    x1=.38: x4=.62: y4=1!
    s1=9282.1
IF t<=274 THEN
 'BLAST PAN (2ND HALF)
     f12=2!: f23=1!: f34=.54
     f21=1.46: f32=.46: f43=0!
    x1=.51: x4=.49: y4=1!
   s1=0
IF t<=264 THEN
 'EMPTY
 TC=TC
     f12=.38: f23=.38: f34=.38
     f21=0!: f32=0!: f43=0!
    x1=.38: x4=.62: y4=1!
   s1=0!
IF t<=259! THEN
      s1=5486.8-2194.7*(t-256.5)
IF t<=256.5 THEN
'PAINT PAN (PRIME - 1ST HALF)
TC=TC+C1*h
     f12=1!: f23=.38: f34=.38
     f21=.62: f32=0!: f43=0!
    x1=.38: x4=.62: y4=1!
    s1=5489.9
IF t<=253.5 THEN
      s1=9220-18438!*(t-253)
IF t<=253 THEN
'WASH PRIME PAN (1ST HALF)
     f12=1!: f23=.38: f34=.38
     f21=.62: f32=0!: f43=0!
    x1=.38: x4=.62: y4=1!
    s1=9282.1
IF t<=250 THEN
 'BLAST PAN ( 1ST  HALF)
     f12=2!: f23=1!: f34=.54
     f21=1.46: f32=.46: f43=0!
    x1=.51: x2=.49: y4=1!
    s1=0
```

```
    cavg=(Ca+Cb+Cd+Ce+Ch+Cj+Ck+Cl+Cm+Cp)/10
IF t<=240 THEN
 'EMPTY
 TC=TC
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
    Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
     f12=0!: f21=0!: f23=0!: f32=0!: f34=0!: f43=0!
    cavg=0!
IF t<=224 THEN
        Sp=2838.2-567.6*(t-219)
IF t<=222.5 THEN
       Sm=2838.2-567.6*(t-217.5)
       Sp=2838.2-567.6*(t-219)
IF t<=219 THEN
 'PAINT P (2-TOP)
 TC=TC+Cp*h
       fab=.5:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=1!:fap=1!
       fba=1!:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=.5:fpa=1.5
    Xp=0!: Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!
       Sm=2838.2-567.6*(t-217.5)
     Sp=2871.1
 IF t<=217.5 THEN
'PAINT M (2-TOP)
TC=TC+Cm*h
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=1!:fmp=1.5:fap=.5
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=.5:fpm=1!:fpa=1!
    Xm=0!: Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!
     Sm=2871.1
    Sp=0!
IF t<=216 THEN
 'EMPTY
 TC=TC
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
    Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=201.5 THEN
        Sp=2838.2-567.6*(t-196.5)
IF t<=200 THEN
        Sm=2838.2-567.6*(t-195)
        Sp=2838.2-567.6*(t-196.5)
```

```
IF t<=198.5 THEN
      Sl=2838.2-567.6*(t-193.5)
      Sm=2838.2-567.6*(t-195)
      Sp=2838.2-567.6*(t-196.5)
IF t<=196.5 THEN
 'PAINT P (1-TOP)
 TC=TC+Cp*h
      fab=.5:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=1!:fap=1!
      fba=1!:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=.5:fpa=1.5
   Xp=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!
      Sl=2838.2-567.6*(t-193.5)
      Sm=2838.2-567.6*(t-195)
    Sp=2871.1
IF t<=195 THEN
'PAINT M (1-TOP)
TC=TC+Cm*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=1!:fmp=1.5:fap=.5
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=.5:fpm=1!:fpa=1!
   Xm=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!
      Sl=2838.2-567.6*(t-193.5)
    Sm=2871.1
   Sp=0!
IF t<=193.5 THEN
 'PAINT L (2-TOP)
 TC=TC+Cl*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=1!:flm=1.5:fmp=1!:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=.5:fml=1!:fpm=.5:fpa=.5
   Xl=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!
    Sl=2871.1
   Sm=0!: Sp=0!
IF t<=192 THEN
'EMPTY
TC=TC
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=182.5 THEN
      Sl=2838.2-567.6*(t-177.5)
IF t<=181.5 THEN
      Sp=2549.3-364.2*(t-174.5)
IF t<=181 THEN
```

```
        Sk=2838.2-567.6*(t-176)
        Sl=2838.2-567.6*(t-177.5)
        Sp=2549.3-364.2*(t-174.5)
IF t<=180 THEN
        Sm=2549.3-364.2*(t-173)
        Sp=2549.3-364.2*(t-174.5)
IF t<=177.5 THEN
'PAINT L (1-TOP)
TC=TC+Cl*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=1!:flm=1.5:fmp=1!:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=.5:fml=1!:fpm=.5:fpa=.5
   Xl=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!
      Sk=2838.2-567.6*(t-176)
    Sl=2871.1
      Sm=2549.3-364.2*(t-173)
      Sp=2549.3-364.2*(t-174.5)
IF t<=176.5 THEN
       Sj=2838.2-567.6*(t-171.5)
       Sk=2838.2-567.6*(t-176)
    Sl=2871.1
       Sm=2549.3-364.2*(t-173)
       Sp=2549.3-364.2*(t-174.5)
IF t<=176 THEN
'PAINT K (2-TOP)
TC=TC+Ck*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=1!:fkl=1.5:flm=1!:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=.5:flk=1!:fml=.5:fpm=0:fpa=.5
   Xk=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!
      Sj=2838.2-567.6*(t-171.5)
    Sk=2871.1
    Sl=0!
      Sm=2549.3-364.2*(t-173)
      Sp=2549.3-364.2*(t-174.5)
IF t<=174.5 THEN
 'PAINT P (INT)
 TC=TC+Cp*h
      fab=.5:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=1!:fap=1!
      fba=1!:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=.5:fpa=1.5
   Xp=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!
      Sj=2838.2-567.6*(t-171.5)
   Sk=0!: Sl=0!
      Sm=2549.3-364.2*(t-173)
```

```
    Sp=2600.6
IF t<=174 THEN
       Sl=2549.3-364.2*(t-167)
       Sm=2549.3-364.2*(t-173)
    Sp=2600.6
IF t<=173 THEN
 'PAINT M (INT)
 TC=TC+Cm*h
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=1!:fmp=1.5:fap=.5
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=.5:fpm=1!:fpa=1!
    Xm=0!: Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!
       Sj=2838.2-567.6*(t-171.5)
    Sk=0!
       Sl=2549.3-364.2*(t-167)
    Sm=2600.6
    Sp=0!
IF t<=171.5 THEN
 'PAINT J (2-TOP)
 TC=TC+Cj*h
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=.5:fjk=1.5:fkl=1!:flm=.5:fmp=.5:fap=0!
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.62:fkj=1!:flk=.5:fml=0!:fpm=0!:fpa=.5
    Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!
     Sj=2871.1
    Sk=0!
       Sl=2549.3-364.2*(t-167)
    Sm=0!: Sp=0!
IF t<=170.5 THEN
        Sk=2838.2-567.6*(t-165.5)
        Sl=2549.3-364.2*(t-167)
IF t<=170 THEN
'EMPTY
TC=TC
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
    Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!
       Sk=2838.2-567.6*(t-165.5)
       Sl=2549.3-364.2*(t-167)
    Sm=0!: Sp=0!
IF t<=167 THEN
 'PAINT L (INT)
 TC=TC+Cl*h
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=1!:flm=1.5:fmp=1!:fap=0!
```

```
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=.5:fml=1!:fpm=.5:fpa=.5
    Xl=0!: Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!
       Sk=2838.2-567.6*(t-165.5)
     Sl=2600.6
    Sm=0!: Sp=0!
IF t<=166.5 THEN
        Sp=4459.4-1783.8*(t-164)
IF t<=165.5 THEN
 'PAINT K (1-TOP)
 TC=TC+Ck*h
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=1!:fkl=1.5:flm=1!:fmp=.5:fap=0!
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=.5:flk=1!:fml=.5:fpm=0!:fpa=.5
    Xk=0!: Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!
     Sk=2871.1
    Sl=0!: Sm=0!
       Sp=4459.4-1783.8*(t-164)
IF t<=164 THEN
'PAINT P (PRIME)
TC=TC+Cp*h
       fab=.5:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=1!:fap=1!
       fba=1!:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=.5:fpa=1.5
    Xp=0!: Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!
     Sp=4527.3
IF t<=162.5 THEN
       Sp=9083!-18166!*(t-162!)
IF t<=162! THEN
'WASH PRIME P
       fab=.5:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=1!:fap=1!
       fba=1!:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=.5:fpa=1.5
    Xp=0!: Xb=.38: Xj=.62
     Sp=9139.5
IF t<=160.5 THEN
    Sp=0!
IF t<=159.5 THEN
 'BLAST P
       fab=1!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.34:fkl=.34:flm=.34:fmp=1.34:fap=2!
       fba=1.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=1!:fpa=2.5
    Xp=.13: Xb=.38: Xj=.49
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=156.5 THEN
        Sm=4459.4-1783.8*(t-154)
 F t<=154 THEN
```

```
'PAINT M (PRIME)
TC=TC+Cm*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=1!:fmp=1.5:fap=.5
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=.5:fpm=1!:fpa=1!
   Xm=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!
    Sm=4527.3
   Sp=0!
IF t<=152.5 THEN
      Sm=9083!-18166!*(t-152!)
IF t<=152! THEN
'WASH PRIME M
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=1!:fmp=1.5:fap=.5
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=.5:fpm=1!:fpa=1!
   Xm=0!: Xb=.38: Xj=.62
    Sm=9139.5
IF t<=150.5 THEN
   Sm=0!
IF t<=149.5 THEN
'BLAST M
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.34:fkl=.34:flm=1.34:fmp=2.5:fap=1!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=1!:fpm=2!:fpa=1.5
   Xm=.13: Xb=.38: Xj=.49
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=144 THEN
 'EMPTY
 TC=TC
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=141.5 THEN
      Sk=2549.3-364.2*(t-134.5)
IF t<=138 THEN
       Sj=2838.2-567.6*(t-133)
       Sk=2549.3-364.2*(t-134.5)
IF t<=136.5 THEN
      Sh=2838.2-567.6*(t-131.5)
      Sj=2838.2-567.6*(t-133)
      Sk=2549.3-364.2*(t-134.5)
IF t<=134.5 THEN
 'PAINT K (INT)
 TC=TC+Ck*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=1!:fkl=1.5:flm=1!:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=.5:flk=1!:fml=.5:fpm=0!:fpa=.5
```

```
   Xk=0!: Xb=.38: Xj=.62
  Sa=0: Sb=0!: Sd=0!: Se=0!
     Sh=2838.2-567.6*(t-131.5)
     Sj=2838.2-567.6*(t-133)
   Sk=2600.6
  Sl=0!: Sm=0!: Sp=0!
IF t<=133 THEN
'PAINT J (1-TOP)
TC=TC+Cj*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=.5:fjk=1.5:fkl=1!:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.62:fkj=1!:flk=.5:fml=0!:fpm=0!:fpa=.5
   Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!
      Sh=2838.2-567.6*(t-131.5)
    Sj=2871.1
   Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=132.5 THEN
      Sl=4459.4-1783.8*(t-130)
IF t<=131.5 THEN
 'PAINT H (2-TOP)
 TC=TC+Ch*h
      fab=0!:fbd=0!:fde=0!:feh=.5:fhj=1!:fjk=1!:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.62:fjh=1.12:fkj=.5:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xh=0!: Xb=.38: Xj=.62
  Sa=0: Sb=0!: Sd=0!: Se=0!
   Sh=2871.1
   Sj=0!: Sk=0!
     Sl=4459.4-1783.8*(t-130)
  Sm=0!: Sp=0!
IF t<=130! THEN
'PAINT L (PRIME)
TC=TC+Cl*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=1!:flm=1.5:fmp=1!:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=.5:fml=1!:fpm=.5:fpa=.5
   Xl=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!
    Sl=4527.3
   Sm=0!: Sp=0!
F t<=128.5 THEN
      Sl=9083!-18166!*(t-128!)
F t<=128! THEN
WASH PRIME L
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=1!:flm=1.5:fmp=1!:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=.5:fml=1!:fpm=.5:fpa=.5
   Xl=0!: Xb=.38: Xj=.62
```

```
    Sl=9139.5
IF t<=126.5 THEN
    Sl=0!
IF t<=125.5 THEN
'BLAST L
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.34:fkl=1.34:flm=2.5:fmp=1.5:fap=0!
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=1!:fml=2!:fpm=1!:fpa=.5
    Xl=.13: Xb=.38: Xj=.49
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=120 THEN
 'EMPTY
 TC=TC
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
    Xb=.38: Xj=.62
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=119 THEN
        Sj=2549.3-364.2*(t-112)
IF t<=115.5 THEN
        Sh=2838.2-567.6*(t-110.5)
        Sj=2549.3-364.2*(t-112)
IF t<=114 THEN
        Se=2838.2-567.6*(t-109)
        Sh=2838.2-567.6*(t-110.5)
        Sj=2549.3-364.2*(t-112)
IF t<=112.5 THEN
        Sd=2838.2-567.6*(t-107.5)
        Se=2838.2-567.6*(t-109)
        Sh=2838.2-567.6*(t-110.5)
        Sj=2549.3-364.2*(t-112)
IF t<=112 THEN
 'PAINT J (INT)
 TC=TC+Cj*h
       fab=0!:fbd=0!:fde=0!:feh=0!:fhj=.5:fjk=1.5:fkl=1!:flm=.5:fmp=.5:fap=0!
       fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.62:fkj=1!:flk=.5:fml=0!:fpm=0!:fpa=.5
    Xb=.38: Xj=.62
    Sa=0: Sb=0!
       Sd=2838.2-567.6*(t-107.5)
       Se=2838.2-567.6*(t-109)
       Sh=2838.2-567.6*(t-110.5)
     Sj=2600.6
    Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=110.5 THEN
 PAINT H (1-TOP)
TC=TC+Ch*h
```

```
      fab=0!:fbd=0!:fde=0!:feh=.5:fhj=1!:fjk=1!:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.62:fjh=1.12:fkj=.5:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xh=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!
      Sd=2838.2-567.6*(t-107.5)
      Se=2838.2-567.6*(t-109)
    Sh=2871.1
   Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=109 THEN
 'PAINT E (2-TOP)
 TC=TC+Ce*h
      fab=0!:fbd=0!:fde=.5:feh=1!:fhj=.5:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.62:fhe=1.12:fjh=.62:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xe=0!: Xb=.38: Xj=.62
   Sa=0!: Sb=0!
      Sd=2838.2-567.6*(t-107.5)
    Se=2871.1
   Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=108.5 THEN
      Sd=2838.2-567.6*(t-107.5)
      Sk=4459.4-1783.8*(t-106)
IF t<=107.5 THEN
 'PAINT D (2-TOP)
 TC=TC+Cd*h
      fab=0!:fbd=.5:fde=1!:feh=.5:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.62:fed=1.12:fhe=.62:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xd=0!: Xb=.38: Xj=.62
    Sd=2871.1
   Sa=0: Sb=0!:Se=0!: Sh=0!: Sj=0!
      Sk=4459.4-1783.8*(t-106)
   Sl=0!: Sm=0!: Sp=0!
IF t<=106 THEN
 'PAINT K (PRIME)
 TC=TC+Ck*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=1!:fkl=1.5:flm=1!:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=.5:flk=1!:fml=.5:fpm=0!:fpa=.5
   Xk=0!: Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!
    Sk=4527.3
   Sl=0!: Sm=0!: Sp=0!
IF t<=104.5 THEN
      Sk=9083!-18166!*(t-104!)
IF t<=104! THEN
WASH PRIME K
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=1!:fkl=1.5:flm=1!:fmp=.5:fap=0!
```

```
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=.5:flk=1!:fml=.5:fpm=0!:fpa=.5
    Xk=0!: Xb=.38: Xj=.62
     Sk=9139.5
IF t<=102.5 THEN
    Sk=0!
IF t<=101.5 THEN
 'BLAST K
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=1.34:fkl=2.5:flm=1.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=1!:flk=2!:fml=1!:fpm=0!:fpa=.5
    Xk=.13: Xb=.38: Xj=.49
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=96.5 THEN
      Sh=2549.3-364.2*(t-89.5)
IF t<= 96 THEN
 'EMPTY
 TC=TC
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
    Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!
      Sh=2549.3-364.2*(t-89.5)
    Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=93 THEN
      Se=2838.2-567.6*(t-88)
      Sh=2549.3-364.2*(t-89.5)
IF t<=91.5 THEN
      Sd=2838.2-567.6*(t-86.5)
      Se=2838.2-567.6*(t-88)
      Sh=2549.3-364.2*(t-89.5)
IF t<=90 THEN
      Sb=2838.2-567.6*(t-85)
      Sd=2838.2-567.6*(t-86.5)
      Se=2838.2-567.6*(t-88)
      Sh=2549.3-364.2*(t-89.5)
IF t<=89.5 THEN
'PAINT H (INT)
TC=TC+Ch*h
      fab=0!:fbd=0!:fde=0!:feh=.5:fhj=1!:fjk=1!:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.62:fjh=1.12:fkj=.5:flk=0!:fml=0!:fpm=0!:fpa=.5
    Xh=0!: Xb=.38: Xj=.62
    Sa=0!
      Sb=2838.2-567.6*(t-85)
      Sd=2838.2-567.6*(t-86.5)
      Se=2838.2-567.6*(t-88)
     Sh=2600.6
```

```
   Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=88.5 THEN
      Sa=2838.2-567.6*(t-83.5)
      Sb=2838.2-567.6*(t-85)
      Sd=2838.2-567.6*(t-86.5)
      Se=2838.2-567.6*(t-88)
    Sh=2600.6
IF t<=88 THEN
 'PAINT E (1-TOP)
 TC=TC+Ce*h
      fab=0!:fbd=0!:fde=.5:feh=1!:fhj=.5:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.62:fhe=1.12:fjh=.62:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xe=0!: Xb=.38: Xj=.62
      Sa=2838.2-567.6*(t-83.5)
      Sb=2838.2-567.6*(t-85)
      Sd=2838.2-567.6*(t-86.5)
    Se=2871.1
   Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<= 86.5 THEN
 'PAINT D (1-TOP)
 TC=TC+Cd*h
      fab=0!:fbd=.5:fde=1!:feh=.5:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.62:fed=1.12:fhe=.62:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xd=0!: Xb=.38: Xj=.62
      Sa=2838.2-567.6*(t-83.5)
      Sb=2838.2-567.6*(t-85)
    Sd=2871.1
   Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=85 THEN
'PAINT B (2-TOP)
TC=TC+Cb*h
      fab=.5:fbd=1!:fde=.5:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
      fba=1!:fdb=1.12:fed=.62:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
   Xb=.38: Xj=.62
      Sa=2838.2-567.6*(t-83.5)
    Sb=2871.1
   Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=84.5 THEN
      Sj=4459.4-1783.8*(t-82)
IF t<= 83.5 THEN
'PAINT A (2-TOP)
TC=TC+Ca*h
      fab=1!:fbd=.5:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
      fba=1.5:fdb=.62:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
   Xa=0!: Xb=.38: Xj=.62
```

```
    Sa=2871.1
   Sb=0!: Sd=0!: Se=0!: Sh=0!
      Sj=4459.4-1783.8*(t-82)
   Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=82 THEN
 'PAINT J (PRIME)
 TC=TC+Cj*h
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=.5:fjk=1.5:fkl=1!:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.62:fkj=1!:flk=.5:fml=0!:fpm=0!:fpa=.5
   Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!
    Sj=4527.3
   Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=80.5 THEN
       Sj=9083!-18166!*(t-80!)
IF t<=80! THEN
'WASH PRIME J
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=.5:fjk=1.5:fkl=1!:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.62:fkj=1!:flk=.5:fml=0!:fpm=0!:fpa=.5
   Xb=.38: Xj=.62
     Sj=9139.5
IF t<=78.5 THEN
    Sj=0!
IF t<=77.5 THEN
'BLAST J
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=1!:fjk=2.5:fkl=1.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=1.12:fkj=2!:flk=1!:fml=0!:fpm=0!:fpa=.5
   Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<= 72 THEN
 'EMPTY
 TC=TC
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=71! THEN
       Se=2549.3-364.2*(t-64)
IF t<=69.5 THEN
       Sd=2549.3-364.2*(t-62.5)
       Se=2549.3-364.2*(t-64)
IF t<=66 THEN
       Sb=2838.2-567.6*(t-61)
       Sd=2549.3-364.2*(t-62.5)
       Se=2549.3-364.2*(t-64)
```

```
IF t<=64.5 THEN
      Sa=2838.2-567.6*(t-59.5)
      Sb=2838.2-567.6*(t-61)
      Sd=2549.3-364.2*(t-62.5)
      Se=2549.3-364.2*(t-64)
   Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=64 THEN
'PAINT E (INT)
TC=TC+Ce*h
     fab=0!:fbd=0!:fde=.5:feh=1!:fhj=.5:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
     fba=.5:fdb=.12:fed=.62:fhe=1.12:fjh=.62:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
  Xe=0!: Xb=.38: Xj=.62
     Sa=2838.2-567.6*(t-59.5)
     Sb=2838.2-567.6*(t-61)
     Sd=2549.3-364.2*(t-62.5)
   Se=2600.6
  Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=62.5 THEN
 'PAINT D (INT)
 TC=TC+Cd*h
     fab=0!:fbd=.5:fde=1!:feh=.5:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
     fba=.5:fdb=.62:fed=1.12:fhe=.62:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
  Xd=0!: Xb=.38: Xj=.62
     Sa=2838.2-567.6*(t-59.5)
     Sb=2838.2-567.6*(t-61)
   Sd=2600.6
  Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=61 THEN
 'PAINT B (1-TOP)
 TC=TC+Cb*h
     fab=.5:fbd=1!:fde=.5:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
     fba=1!:fdb=1.12:fed=.62:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
  Xb=.38: Xj=.62
     Sa=2838.2-567.6*(t-59.5)
   Sb=2871.1
  Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=60.5 THEN
      Sh=4459.4-1783.8*(t-58)
 IF t<=59.5 THEN
 'PAINT A (1-TOP)
 TC=TC+Ca*h
     fab=1!:fbd=.5:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
     fba=1.5:fdb=.62:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
  Xa=0!: Xb=.38: Xj=.62
   Sa=2871.1
```

```
   Sb=0!: Sd=0!: Se=0!
      Sh=4459.4-1783.8*(t-58)
   Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=58 THEN
'PAINT H (PRIME)
TC=TC+Ch*h
      fab=0!:fbd=0!:fde=0!:feh=.5:fhj=1!:fjk=1!:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.62:fjh=1.12:fkj=.5:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xh=0!: Xb=.38: Xj=.62
    Sh=4527.3
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=56.5 THEN
      Sh=9083!-18166!*(t-56!)
IF t<=56! THEN
'WASH PRIME H
      fab=0!:fbd=0!:fde=0!:feh=.5:fhj=1!:fjk=1!:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.62:fjh=1.12:fkj=.5:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xh=0!: Xb=.38: Xj=.62
    Sh=9139.5
IF t<=54.5 THEN
   Sh=0!
IF t<=54 THEN
      Sb=2549.3-364.2*(t-47)
IF t<=53.5 THEN
'BLAST H
      fab=0!:fbd=0!:fde=0!:feh=1!:fhj=2!:fjk=1!:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=1.12:fjh=1.96:fkj=.5:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xh=.13: Xb=.38: Xj=.49
      Sb=2549.3-364.2*(t-47)
   Sa=0: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=52.5 THEN
      Sa=2549.3-364.2*(t-45.5)
      Sb=2549.3-364.2*(t-47)
IF t<=48 THEN
 'EMPTY
 TC=TC
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xb=.38: Xj=.62
      Sa=2549.3-364.2*(t-45.5)
      Sb=2549.3-364.2*(t-47)
   Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=47 THEN
 'PAINT B (INT)
 TC=TC+Cb*h
```

```
      fab=.5:fbd=1!:fde=.5:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
      fba=1!:fdb=1.12:fed=.62:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
   Xb=.38: Xj=.62
      Sa=2549.3-364.2*(t-45.5)
   Sb=2600.6
   Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=46.5 THEN
      Se=4459.4-1783.8*(t-44)
IF t<=45.5 THEN
'PAINT A (INT)
TC=TC+Ca*h
      fab=1!:fbd=.5:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
      fba=1.5:fdb=.62:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
   Xa=0!: Xb=.38: Xj=.62
   Sa=2600.6
      Se=4459.4-1783.8*(t-44)
   Sb=0!: Sd=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=44 THEN
 'PAINT E (PRIME)
 TC=TC+Ce*h
      fab=0!:fbd=0!:fde=.5:feh=1!:fhj=.5:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.62:fhe=1.12:fjh=.62:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xe=0!: Xb=.38: Xj=.62
   Se=4527.3
   Sa=0: Sb=0!: Sd=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=42.5 THEN
      Se=9083!-18166!*(t-42!)
IF t<= 42! THEN
'WASH PRIME E
      fab=0!:fbd=0!:fde=.5:feh=1!:fhj=.5:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.62:fhe=1.12:fjh=.62:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xe=0!: Xb=.38: Xj=.62
   Se=9139.5
IF t<= 40.5 THEN
   Se=0!
IF t<=39.5 THEN
 'BLAST E
      fab=0!:fbd=0!:fde=1!:feh=2!:fhj=1!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=1.12:fhe=1.96:fjh=.96:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xe=.13: Xb=.38: Xj=.49
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=36.5 THEN
      Sd=4459.4-1783.8*(t-34)
   Sa=0: Sb=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=34 THEN
```

```
'PAINT D (PRIME)
TC=TC+Cd*h
      fab=0!:fbd=.5:fde=1!:feh=.5:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.62:fed=1.12:fhe=.62:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xd=0!: Xb=.38: Xj=.62
    Sd=4527.3
   Sa=0: Sb=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=32.5 THEN
      Sd=9083!-18166!*(t-32!)
   Sa=0: Sb=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<= 32! THEN
'WASH PRIME D
      fab=0!:fbd=.5:fde=1!:feh=.5:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.62:fed=1.12:fhe=.62:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xd=0!: Xb=.38: Xj=.62
    Sd=9139.5
   Sa=0: Sb=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<= 30.5 THEN
   Sd=0!
   Sa=0: Sb=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=29.5 THEN
'BLAST D
      fab=0!:fbd=1!:fde=2!:feh=1!:fhj=.04:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=1.12:fed=1.96:fhe=.96:fjh=0!:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xd=.13: Xb=.38: Xj=.49
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
 IF t<=24 THEN
'EMPTY
TC=TC
      fab=0!:fbd=0!:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=.5:fdb=.12:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xb=.38: Xj=.62
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=22.5 THEN
      Sb=4459.4-1783.8*(t-20)
   Sa=0:  Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=20 THEN
'PAINT B (PRIME)
TC=TC+Cb*h
      fab=.5:fbd=1!:fde=.5:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
      fba=1!:fdb=1.12:fed=.62:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
   Xb=.38: Xj=.62
    Sb=4527.3
   Sa=0:  Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=18.5 THEN
```

```
      Sb=9083!-18166!*(t-18)
   Sa=0:  Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=18! THEN
'WASH PRIME B
      fab=.5:fbd=1!:fde=.5:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
      fba=1!:fdb=1.12:fed=.62:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
   Xb=.38: Xj=.62
    Sb=9139.5
   Sa=0:  Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=16.5 THEN
   Sb=0!
   Sa=0:  Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=15.5 THEN
 'BLAST B
      fab=1!:fbd=2!:fde=1!:feh=.04:fhj=.04:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=0!
      fba=1.5:fdb=1.96:fed=.96:fhe=0!:fjh=0!:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=.5
   Xb=.51: Xj=.49
   Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=12.5 THEN
      Sa=4459.4-1783.8*(t-10)
   Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=10 THEN
 'PAINT A (PRIME)
 TC=TC+Ca*h
      fab=1!:fbd=.5:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
      fba=1.5:fdb=.62:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
   Xa=0!: Xb=.38: Xj=.62
    Sa=4527.3
   Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: S=0!
IF t<= 8.5 THEN
      Sa=9083!-18166!*(t-8!)
   Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<= 8! THEN
'WASH PRIME A
      fab=1!:fbd=.5:fde=0!:feh=0!:fhj=0!:fjk=.5:fkl=.5:flm=.5:fmp=.5:fap=.5
      fba=1.5:fdb=.62:fed=.12:fhe=.12:fjh=.12:fkj=0!:flk=0!:fml=0!:fpm=0!:fpa=1!
   Xa=0!: Xb=.38: Xj=.62
    Sa=9139.5
   Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<= 6.5 THEN
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
IF t<=5.5 THEN
 'BLAST A
      fab=2!:fbd=1!:fde=0:feh=0:fhj=0!:fjk=.42:fkl=.42:flm=.42:fmp=.42:fap=1!
      fba=2.42:fdb=1.04:fed=.04:fhe=.04:fjh=.04:fkj=0:flk=0!:fml=0!:fpm=0!:fpa=1.42
```

```
    Xa=.13: Xb=.38: Xj=.49
    Sa=0: Sb=0!: Sd=0!: Se=0!: Sh=0!: Sj=0!: Sk=0!: Sl=0!: Sm=0!: Sp=0!
 END IF
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 END IF
GOTO 50
REM
REM  NEED TO DEFINE A(i), B(i) etc. ONLY WANT PROGRAM TO PRINT OUT CERTAIN VALUE
S OF Ci
50   IF t>=250.01 THEN
          N=N+1
          IF N=51 THEN
              'PRINT t,C1,C2,C3,C4
              'PRINT,t,TC
               'WRITE #1,t,s1
             WRITE  #1,t,C1,C2,C3,C4
               'WRITE #1,t,TC
              N=1
          END IF
          IF t=250.01 THEN
                'PRINT "t (hours)","C1 (g/cum)","C2 (g/cum)","C3 (g/cum)","C4 (g/cum)"
          END IF
    END IF
   IF t<=250 THEN
       N=N+1
   IF N=51 THEN
      'WRITE#1,t,SAT,SBT,SDT,SET,SHT,SJT,SKT,SLT,SMT,SPT
      'PRINT t,Ca,Cb,Cd,Ce,Ch
       'PRINT, t,TC
      WRITE  #1,t,Ca,Cb,Cd,Ce,Ch,Cj,Ck,Cl,Cm,Cp
       'WRITE#1,t,TC
      N=1
    END IF
    END IF
       Aa=(fap*Q+fab*Q+Q+KAD*ASa)/(-Ka*V)
       Ba=(Sa+fpa*Q*Cp+fba*Q*Cb+Xa*Q*Co)/(Ka*V)
```

```
A=Aa: B=Ba: c=Ca
GOSUB Rungekutta
Ca=y
   Ab=(fbd*Q+fba*Q+KAD*ASb)/(-Kb*V)
   Bb=(Sb+fdb*Q*Cd+fab*Q*Ca+Xb*Q*Co)/(Kb*V)
A=Ab: B=Bb: c=Cb
GOSUB Rungekutta
Cb=y
   Ad=(fdb*Q+fde*Q+KAD*ASd)/(-Kd*V)
   Bd=(Sd+fed*Q*Ce+fbd*Q*Cb+Xd*Q*Co)/(Kd*V)
A=Ad: B=Bd: c=Cd
GOSUB Rungekutta
Cd=y
   Ae=(fed*Q+feh*Q+KAD*ASe)/(-Ke*V)
   Be=(Se+fde*Q*Cd+fhe*Q*Ch+Xe*Q*Co)/(Ke*V)
A=Ae: B=Be: c=Ce
GOSUB Rungekutta
Ce=y
    Ah=(fhe*Q+fhj*Q+KAD*ASh)/(-Kh*V)
    Bh=(Sh+feh*Q*Ce+fjh*Q*Cj+Xh*Q*Co)/(Kh*V)
A=Ah: B=Bh: c=Ch
GOSUB Rungekutta
Ch=y
      Aj=(fjh*Q+fjk*Q+KAD*ASj)/(-Kj*V)
      Bj=(Sj+fkj*Q*Ck+fhj*Q*Ch+Xj*Q*Co)/(Kj*V)
 A=Aj: B=Bj: c=Cj
GOSUB Rungekutta
 Cj=y
     Ak=(fkj*Q+fkl*Q+KAD*ASk)/(-Kk*V)
     Bk=(Sk+fjk*Q*Cj+flk*Q*Cl+Xk*Q*Co)/(Kk*V)
A=Ak: B=Bk: c=Ck
GOSUB Rungekutta
Ck=y
      Al=(flk*Q+flm*Q+KAD*ASl)/(-Kl*V)
      Bl=(Sl+fkl*Q*Ck+fml*Q*Cm+Xl*Q*Co)/(Kl*V)
 A=Al: B=Bl: c=Cl
GOSUB Rungekutta
 Cl=y
    Am=(fml*Q+fmp*Q+KAD*ASm)/(-Km*V)
    Bm=(Sm+flm*Q*Cl+fpm*Q*Cp+Xm*Q*Co)/(Km*V)
A=Am: B=Bm: c=Cm
GOSUB Rungekutta
Cm=y
   Ap=(fpm*Q+fpa*Q+KAD*ASp)/(-Kp*V)
   Bp=(Sp+fap*Q*Ca+fmp*Q*Cm+Xp*Q*Co)/(Kp*V)
```

```
      A=Ap: B=Bp: c=Cp
      GOSUB Rungekutta
      Cp=y
          A1=((f12)*Q)/(-k1*V)
          B1=(s1+x1*Q*Co+(f21)*Q*C2)/(k1*V)
      A=A1: B=B1: c=C1+cavg
      GOSUB Rungekutta
      C1=y
          A2=((f21)*Q+(f23)*Q)/(-k2*V)
          B2=((f12)*Q*C1+(f32)*Q*C3)/(k2*V)
      A=A2: B=B2: c=C2+cavg
      GOSUB Rungekutta
      C2=y
          A3=((f32)*Q+(f34)*Q)/(-k3*V)
          B3=((f23)*Q*C2+(f43)*Q*C4)/(k3*V)
      A=A3: B=B3: c=C3+cavg
      GOSUB Rungekutta
      C3=y
          A4=((f43)*Q+y4*Q)/(-k4*V)
          B4=((f34)*Q*C3+x4*Q*Co)/(k4*V)
      A=A4: B=B4: c=C4+cavg
      GOSUB Rungekutta
      C4=y
GOTO 100
REM *** subroutine for fourth order Runge Kutta method
Rungekutta:
     f1=A*c+B
     m1=h*f1
      ci=c+1/2*m1
     f2=A*ci+B
     m2=h*f2
      ci=c+1/2*m2
     f3=A*ci+B
     m3=h*f3
    ci=c+m3
     f4=A*ci+B
     m4=h*f4
       y=c+(m1+(2*m2)+(2*m3)+m4)/6
RETURN
100  t=t+h
WEND
CLOSE
END
```

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